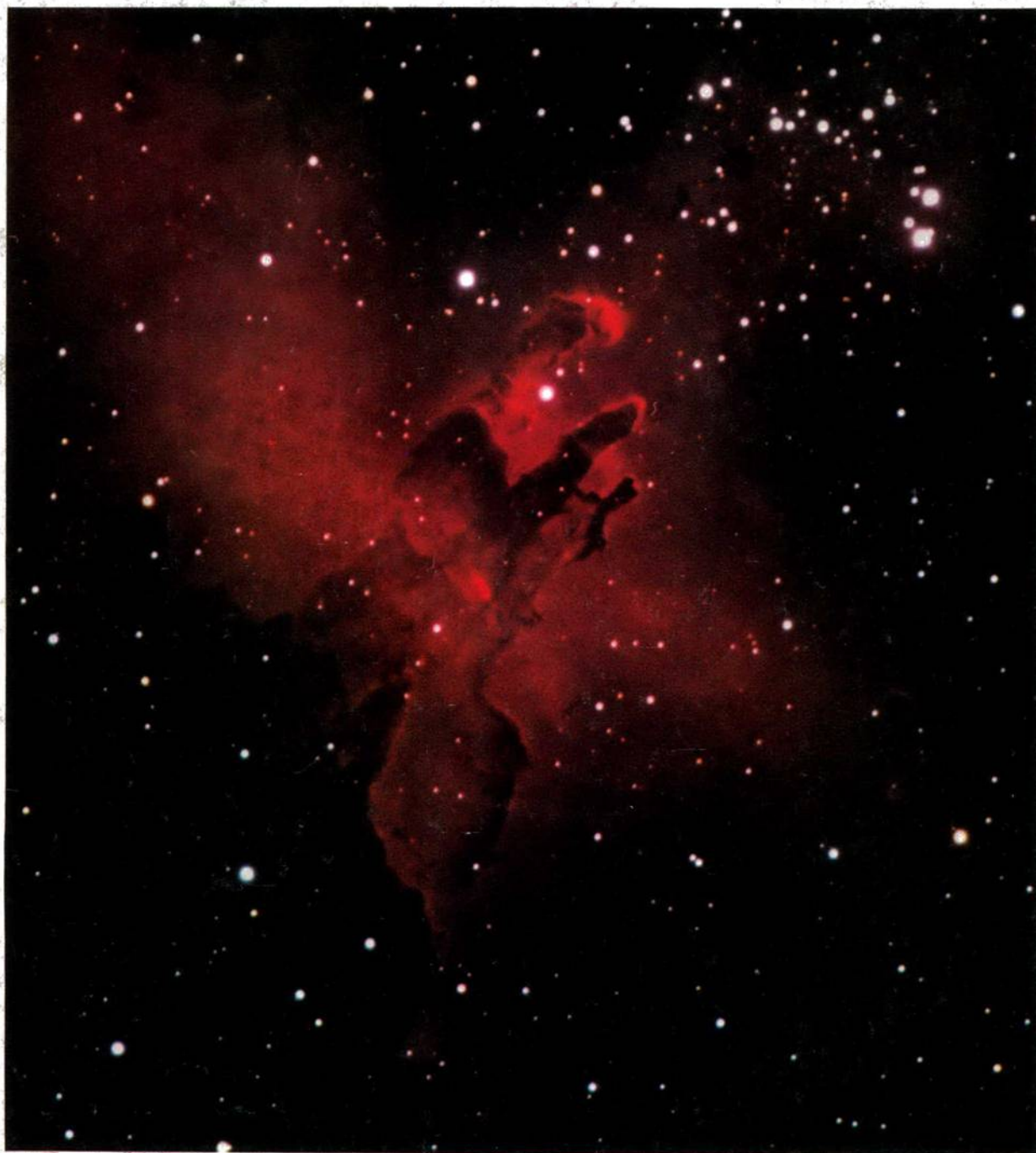


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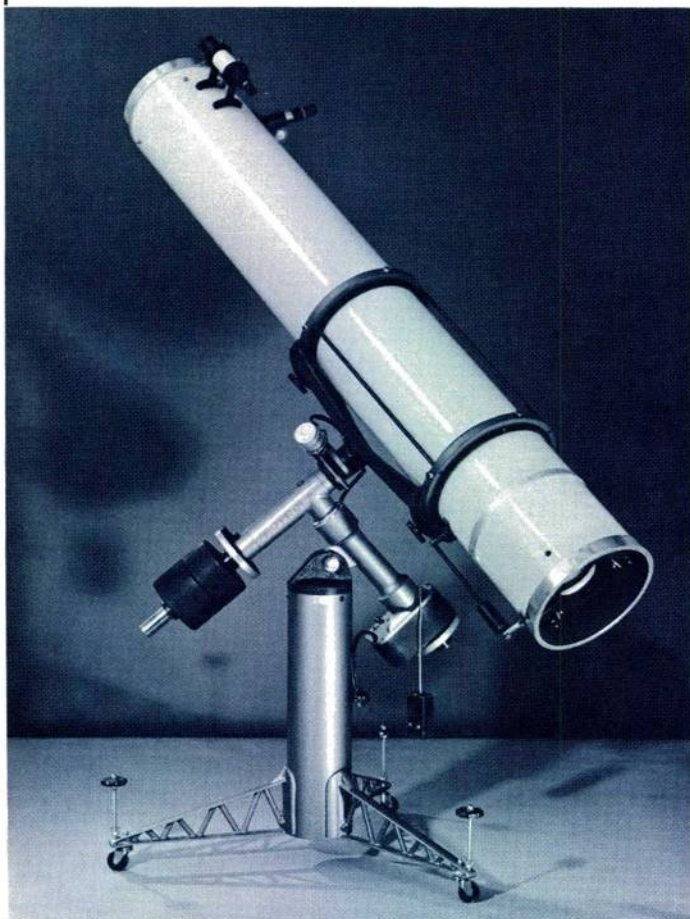
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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

April 1974

Vol. 2, No. 4

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Tongues of darkness protrude into a cavern of luminous gas in this region of the constellation Serpens, forming one of the most beautiful vistas in the known universe. Despite its stunning appearance this nebula has no name, just a number: M-16. Here, smaller dark globules are obvious with the bright nebula behind them. M-16 is 6,000 light-years distant and contains a vast storehouse of matter that will eventually condense into stars, as described in "Between the Stars", page 38.

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The Canals of MARS

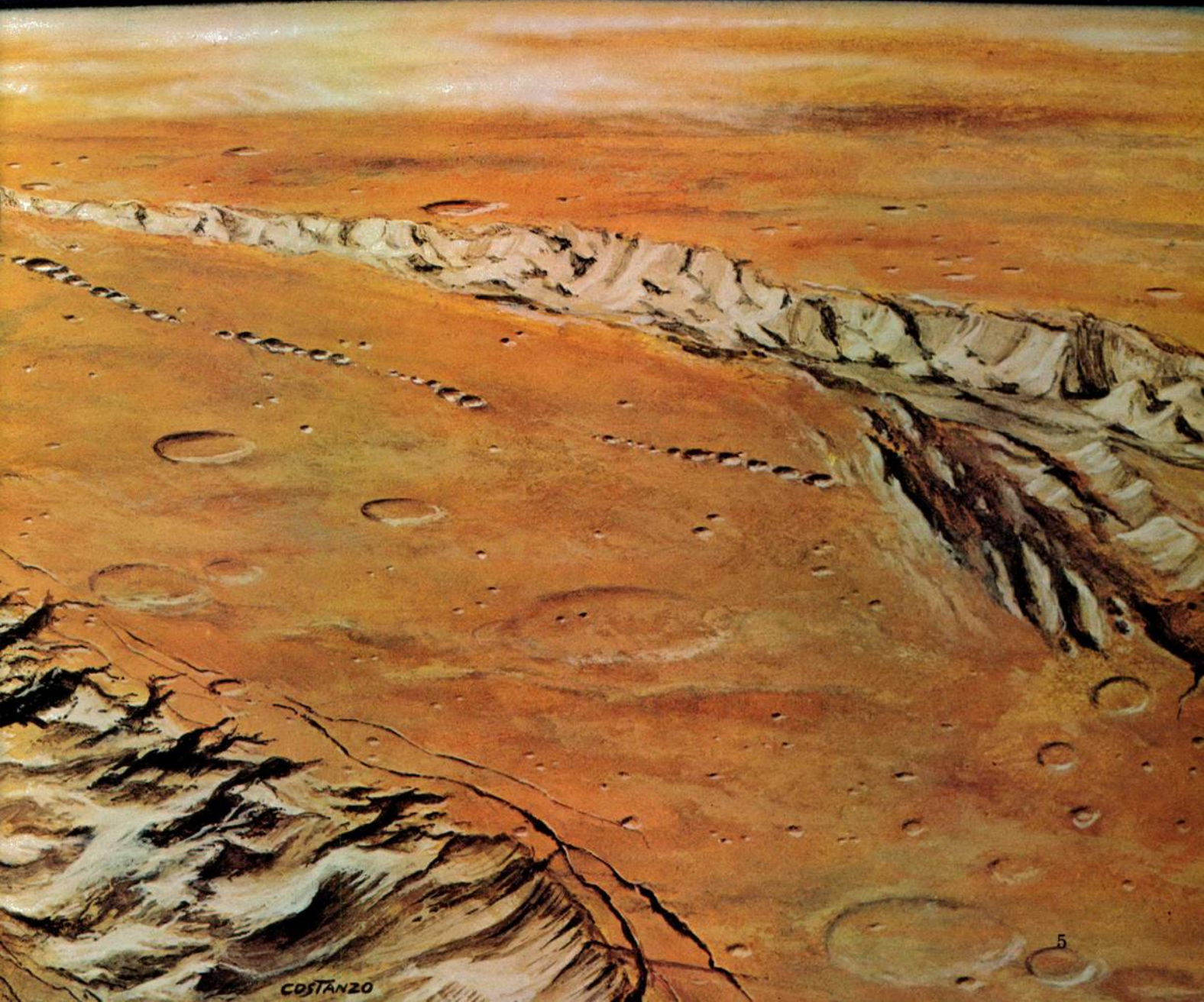
by
Carl Sagan

This article is an excerpt from Dr. Carl Sagan's recent book, **The Cosmic Connection: An Extraterrestrial Perspective**, copyright © 1973 by Carl Sagan and Jerome Agel, published by Doubleday & Company, Inc.

The great canyon of Mars is so vast that it was seen from Earth for nearly a century as the Martian "canal" Coprates. In places it is more than a mile deep and 50 miles wide, and carves a 3,000 mile gash across the red planet. This rendering portrays its appearance from an aerial viewpoint several miles above the most rugged regions of this massive canyon. Future Mars explorers will call this area Vallis Marineris after Mariner 9 which first revealed its existence.

Artwork by Victor Costanzo

In 1887 (as in 1971) the planet Mars was close — 40 million miles from Earth. European astronomers, with newly developed telescopes, prepared for what was then man's most detailed look at our planetary neighbor. One of them was Giovanni Schiaparelli, an Italian observing in Milan and a collateral relative of the late court-





NASA Photograph

Some of the detail seen in this Mariner 7 photo of Mars cannot be observed from Earth, even in the largest telescopes. The spacecraft was 300,000 miles from the planet

on its way to a sweep by the south polar region (bottom). The arrow identifies the old "canal" Coprates that actually turned out to be the feature pictured on page 4.

urier and perfume enterpriser.

Generally speaking, the telescopic view of Mars was blurred and fuzzy, interrupted by the variable turbulence in Earth's atmosphere that astronomers call "seeing". But there were moments when Earth's atmosphere steadied and true detail on the disc of Mars seemed to flash out. Schiaparelli was astonished to see a network of fine straight lines covering the disc of the planet. He called these lines *canali*, which in Italian means "channels". However *canali* was translated into English as "canals", a word with a clear imputation of design.

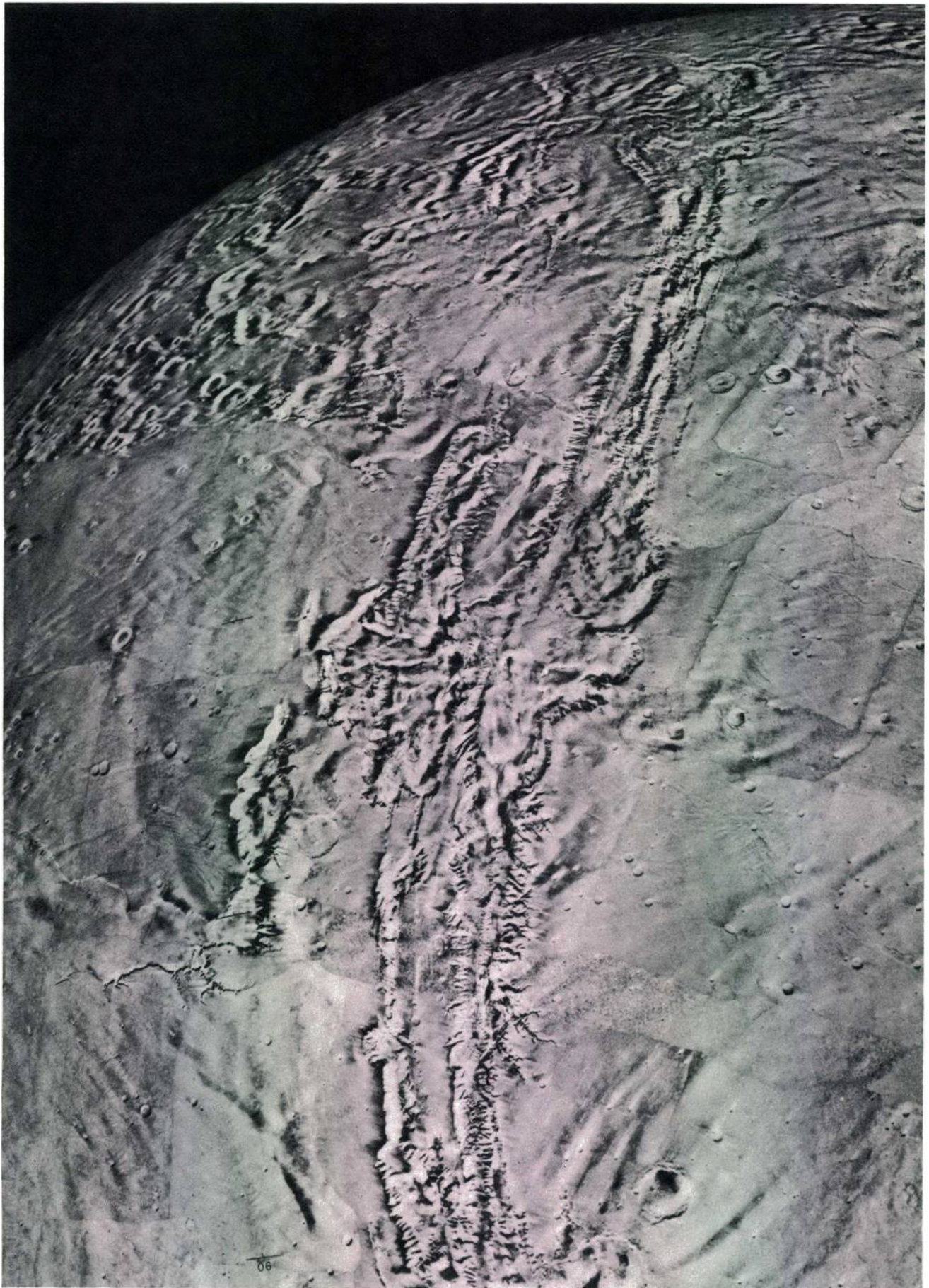
Schiaparelli's observations were taken up by Percival Lowell, a diplomat once posted in Chosen, the present Korea. A Boston Brahmin, the brother of the president of Harvard university and of an even more famous personage, poetess Amy Lowell (for some reason renowned for smoking little black cigars), Lowell established a private observatory in Flagstaff, Ariz., to study the planet Mars. He found the same *canali* that Schiaparelli had, extended their description, and elaborated an explanation.

Mars was, Lowell concluded, a dying world on which intelligent life had arisen and accommodated itself to the perils of the planet. The chief peril was the dearth of water. The Martian civilization, Lowell imagined, had constructed an

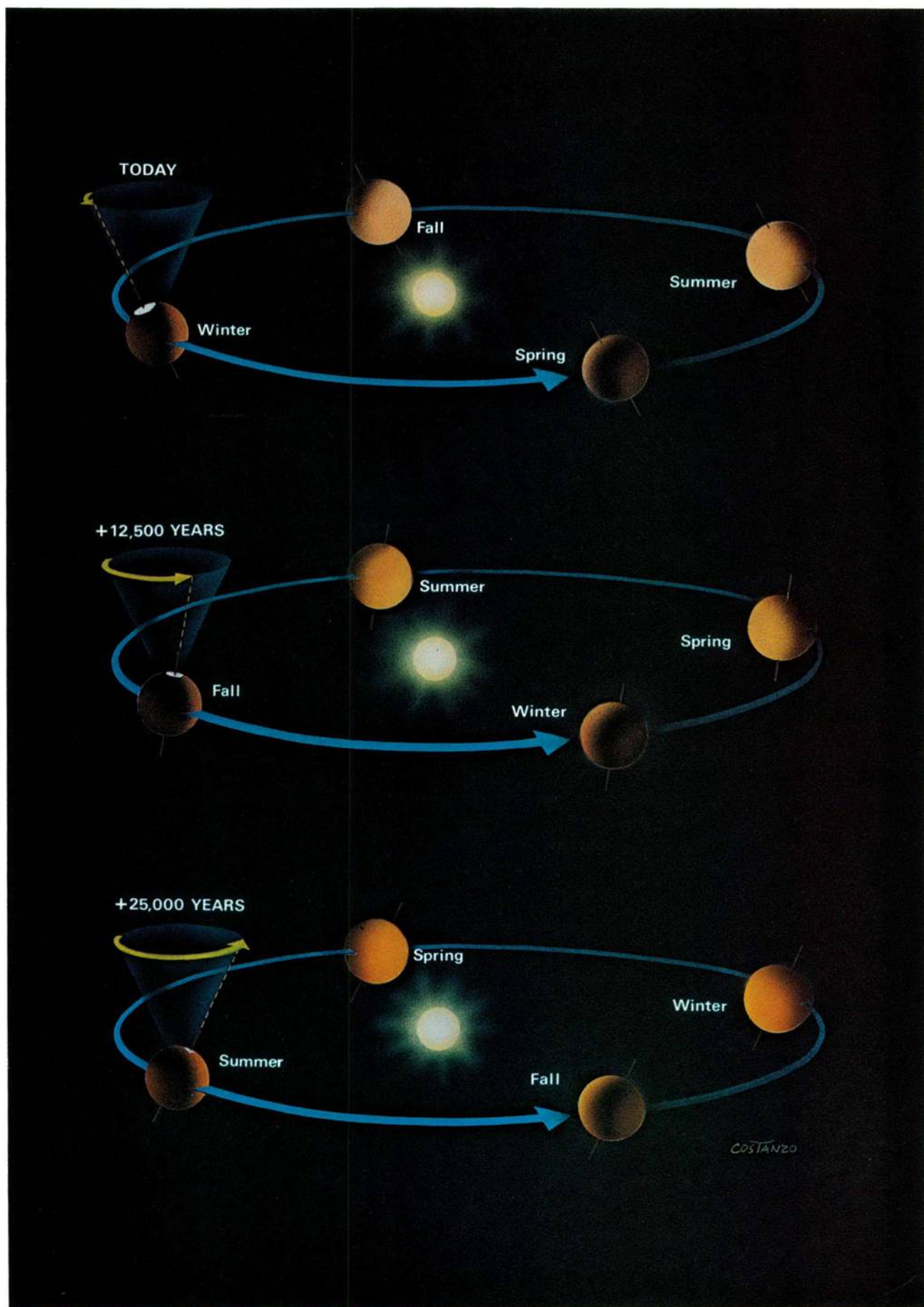
extensive network of canals to carry water from the melting polar caps to the habitations in more equatorial climes. The turning point of the argument was the straightness of the canals, some of them following great circles for thousands of miles. Such geometrical configurations, Lowell thought, could not be produced by geological processes. The lines were too straight. They could only have been produced by intelligence.

This is a conclusion with which we all can agree. The only debate is about which side of the telescope the intelligence was on. Lowell believed that the penchant for Euclidian geometry was on the distant end of the telescope. But the difficulties in drawing a great deal of mottled fine detail in a few seconds of good seeing are so great that the eye-brain-hand combination is sorely tempted to connect such disconnected features into straight lines. Many of the best visual astronomers observing Mars between the turn of the century and the dawn of the space

The great canyonlands of Mars are believed to be a giant rift valley over a mile deep. The center of this picture corresponds to the dark area indicated in the photo on the opposite page. This photo is part of a global mosaic of hundreds of Mariner 9 images that were painstakingly united at NASA's Jet Propulsion Laboratory. While it orbited Mars in 1971-72, Mariner 9 photographed virtually all of Mars.



Jet Propulsion Laboratory Photograph





Artwork by Victor Costanzo

When viewed from Earth, Mars is a difficult target in even the largest telescopes. At the left is its normal visual appearance — an appearance that resulted in many drawings showing straight “canals”. However at the right is a drawing of the same region of Mars, made under excellent con-

ditions, showing that the canals really are a visual illusion. The eye tends to link unrelated features into straight lines — hence the canal controversy. Photos, like the one on page 6, shattered the canal hypothesis once and for all in 1969.

age found that, while they could see canals under conditions of good but not superb seeing, they were able in the extremely rare moments of perfect seeing to resolve the straight lines into a multitude of spots and irregular detail.

Then it was found that at least the vast bulk of the polar caps are carbon dioxide and not frozen water. The atmospheric pressure was discovered to be much less than on Earth. Liquid water was found to be entirely impossible. The idea of advanced forms of life and canals on Mars died. And yet...

A slow wobbling of Mars' axis may control climate changes on the planet. Since the orbit of Mars varies considerably from a circle, it is closer to the sun today during the northern hemisphere winter (top). In 12,500 years both poles will be equally bathed in sunlight at the orbital near-point. This is what Dr. Sagan calls “precessional spring”, a time when the storehouse of water from the northern cap is released. By 25,000 years from now (bottom) the released water from the shrunken northern cap will be locked in the south polar zone.

As the planet-wide dust storm cleared in 1971, the Mariner 9 spacecraft began to photograph a region called Coprates by classical observers. Coprates was one of the largest canali found by Lowell, Schiaparelli, and their followers. Toward the end of the dust storm, Coprates was revealed to be an enormous rift valley running 3,000 miles east to west near the Martian equator, 50 miles wide in spots and a mile deep. It was not perfectly straight — it was certainly not an engineering work; but it was a vast gash proportionately longer than any such feature on Earth.

And running out of Coprates were features that were very curious indeed — sinuous channels, meandering through the highlands above the Coprates valley and graced with beautiful little tributaries. If such channels had been seen on Earth, they would unhesitatingly have been attributed to running water. But on Mars the surface pressures are so low that liquid water would instantly vaporize, just as the pressures on Earth are so low that liquid carbon dioxide vaporizes

instantly. On Earth we have solid carbon dioxide and gaseous carbon dioxide, but not liquid carbon dioxide. On Mars this absence of the liquid phase is true as well for water.

But as the Mariner 9 photographic mission continued, a variety of additional channels were discovered: channels with second and third order tributary systems, channels without a crater at their beginning or end, channels with teardrop shaped islands in their midst, channels with braided termini — like those cut on Earth by episodic flooding.

There seems to be little doubt that most of the several dozen longest channels (the longest are hundreds of miles long), and hundreds of smaller ones, were cut by running water. But since there can be no liquid water on Mars today, the channels must have been cut in a previous epoch of Martian history — when the total pressures were larger, the temperatures higher, and the availability of water greater.

The channels revealed by Mariner 9 speak eloquently of the possibility of massive climatic change on Mars. In this view, Mars is today in the throes of an ice age. But in the past — no one knows just how long ago — it possessed much

more clement and Earthlike conditions.

The reasons for such dramatic climatic changes are still being hotly debated. Before the Mariner 9 launch, I proposed that such climatic changes leading to episodes of liquid water might occur on Mars. They might be driven by the precession of the equinoxes, a well known motion akin to the slow, drifting precession of a rapidly spinning top. The precessional periods on Mars are something like 50 thousand years. If we are now in a precessional winter with an extensive north polar ice cap, 25 thousand years ago may have been the precessional winter with an extensive south polar ice cap.

But 12 thousand years ago may have been the epoch of precessional spring and summer. The dense atmosphere of that time is now locked away in the polar caps. It may have been a time on Mars of balmy temperatures, soft nights, and the trickle of liquid water down innumerable streams and rivulets, rushing out to join mighty, gushing rivers. Some of these rivers would have flowed into the great Coprates rift valley.

If so, 12 thousand years ago was a good time on Mars for life similar to the terrestrial sort. If I were an organism on Mars, I might gear my



From a distance of about 1,000 miles Mariner 9 viewed this sinuous valley that winds for 250 miles over a cratered region of Mars. In places the valley is 4 miles wide and 1,000 feet deep. The author believes such channels were carved by water during a Martian "precessional spring" (see text).

NASA Photograph



activities to the precessional summers and close up shop in the precessional winters — as many organisms do on Earth for our much shorter annual winters. I would make spores; I would make vegetative forms; I would go into cryptobiotic repose; I would hibernate until the long winter had subsided. If this is indeed what Martian organisms do, we may be arriving at Mars 12 thousand years too early — or too late!

But there is a way to test these ideas. One way the hypothetical Martian organisms would know that the precessional spring has arrived is by the reappearance of liquid water. Therefore, as Linda Sagan has mentioned, the recipe for detecting life on Mars is "add water". And this is just what the United States Viking biology experiments, scheduled to land on Mars in 1976 and search for microbes, will do. An automatic arm will drop two samples of Martian soil into liquid water. A third sample will be inserted into a chamber with no liquid water. If the first two experiments give positive biological results, and the third experiment does not, some support will be given to this idea that Martian organisms are

waiting out the long winter.

But it is entirely possible that the designs of these experiments are too "Earth chauvinist". There may be Martian organisms that enjoy the present environment and are drowned in liquid water. The idea of Martian organisms as sleeping beauties, awaiting a somewhat wet kiss from Viking, is a long shot — but a fascinating one.

By no means do all of the channels correspond to the positions of the classical canali drawn by Lowell and Schiaparelli. Some, like Ceraunius, appear to be ridges. Others correspond to no detail that can now be made out. But some, like Coprates, are grooves in the Martian terrain. There *are* channels on Mars. They may have biological implications, of a different sort than Lowell imagined (as the long winter model suggests), or they may have no connection with Martian biology at all.

The canals of Lowell do not exist, but the canali of Schiaparelli are there to be seen, more or less. Perhaps one day in the future, the channels will again be filled with water and, for all we know, with visiting gondoliers from the planet Earth. 

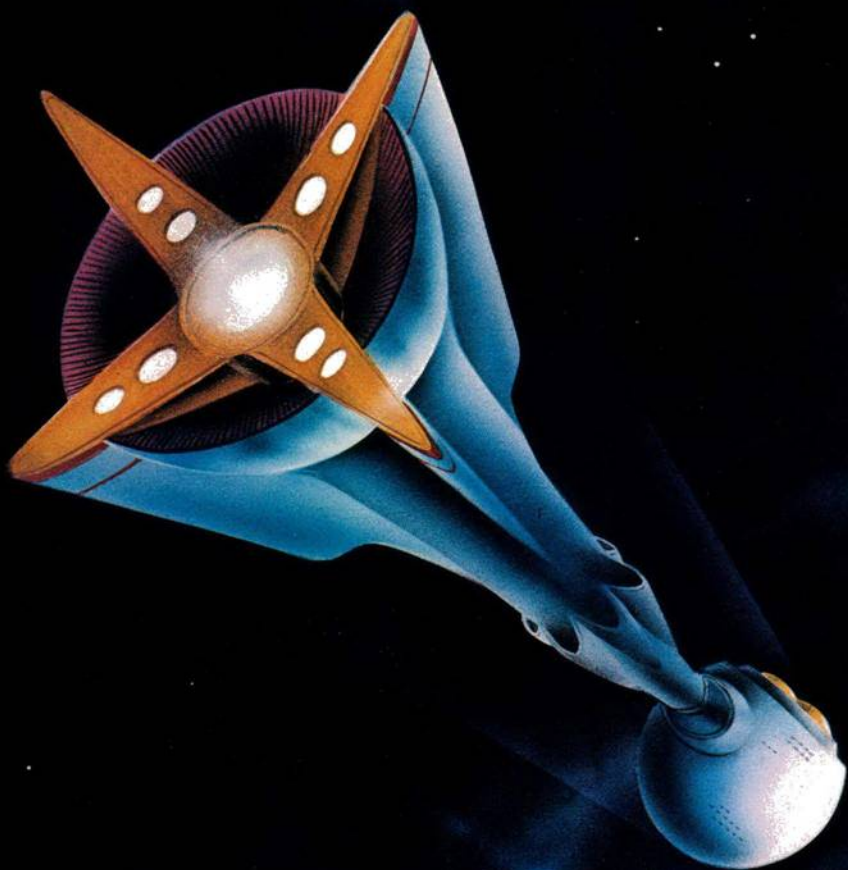
Beyond The Black Hole

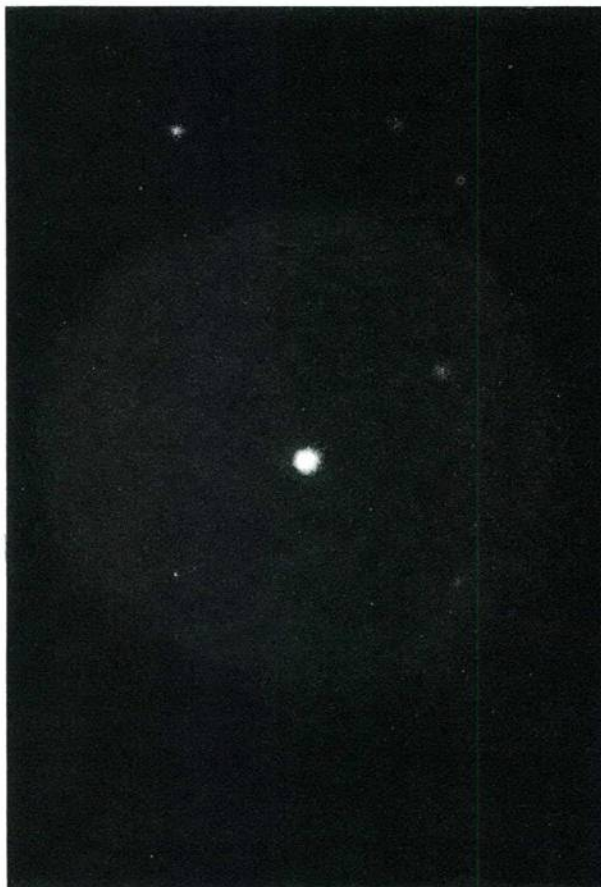
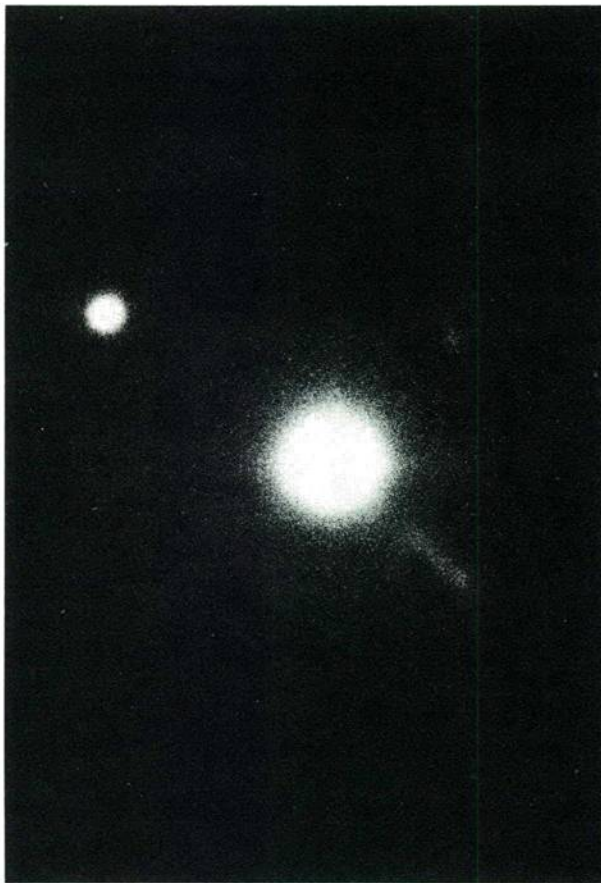
The existence of bizarre gravitational whirlpools in space is now virtually beyond doubt. Black holes exist. Gravity is all-powerful in these cosmic funnels that scoop up matter and energy and fling it on a timeless, plummeting journey. Where there once was a star, there is now nothing but a ghostlike gravitational field that warps space and time and is strictly one-way — what goes in, never comes out. But with the acceptance of the existence of black holes a nag-

ging question emerges. What happens to the matter that swirls out of this universe down the

A starship of the distant future hurtles toward a black hole. At close range black holes likely have glowing exteriors due to a halo of cosmic debris that is attracted toward them. The intense magnetic fields surrounding the hole force the encircling material into luminescence. Black hole theory predicts a space-warp, capable of ejecting the starship into another universe, lies within these bizarre objects.

Artwork by Victor Costanzo





bottomless pit of a gravitational black hole?

Before 1939 black holes did not even exist in the mind of man. In that year Robert Oppenheimer and Hartland Snyder suggested that if a star somewhat more massive than the sun were to lose the forces that hold it up — the production of energy that continuously flows out from the core of a normal star — then the star would collapse under its own weight. The matter falling upon itself would crush the star out of existence leaving behind a cosmic tombstone of intense gravity. Today, there seems to be no doubt that a black hole is the ultimate fate of a dying massive star.

But what happens to the star? What about something that happens to be passing by and follows the one-way path of the former star? And what would happen to a spaceship that flew, intentionally or otherwise, into the abyss of a black hole? In the 1970s, theoretical astronomers are tackling just such questions, and some amazing speculations have emerged.

Now let's get specific. What's a black hole really like up close? Cygnus X-1, discussed in last month's feature article "The Cosmic Abyss", is a black hole that is assimilating the matter of a nearby massive companion star. The two orbit about each other — the black hole and a giant blue star — and the material from the blue star continuously is sucked down the whirlpool of the black hole. Cygnus X-1 is the first black hole to be identified as such.

But suppose we have a situation where the black hole has consumed all the material in its vicinity and is sitting essentially alone among the stars. What's it like? Well, it may have a celestial junkyard in orbit around it. Anything can go into orbit around a black hole, in the same way things orbit the sun. There is a vast collection of material whirling around the sun. And so it may be with a black hole. In fact this seems likely since the creation of the black hole blasted off the outer layers of the star that formed it. Certainly some residual matter ends up in orbit about the black hole. There is also a small quantity of matter in what is commonly called "outer space" that would be continually feeding the hole. If there's a lot of material from various sources, it may look like a cloud perhaps forced into lumin-

The quasar 3C 273 (top) is the brightest and one of the nearest of these baffling objects. Quasars emit prodigious amounts of energy that have defied explanation for a decade. The jet of material extending from 3C 273 is believed to be a massive ejection from the nucleus. Most quasars resemble faint stars like 3C 196 (lower).

Hale Observatories Photograph

escence by the intense magnetic field in the immediate vicinity of the black hole. Several Soviet theorists have suggested that the luminous material may look like a white dwarf star from a distance. (White dwarfs are small dense stars much less luminous than the sun.) Some white dwarfs, when studied spectroscopically, have no visible features — a peculiarity that suggests they may not be white dwarfs but the material around a black hole.

But it's also just as likely that the hole will have a limited amount of orbiting material and will be essentially invisible from distances of a light-year or more. At the present time there is no consensus among astronomers as to what an isolated black hole really looks like.

Black holes can be just about any size above a certain minimum. How can the size of a black hole be measured? The best measure is the dimension of the region called the event horizon — the limit of escape. Even a photon of light going at 186,000 miles per second cannot escape from within this limit. So the event horizon effectively defines the size of a black hole and that size is directly proportional to the mass. The smallest black holes that astronomers are confident exist are equivalent to about twice the mass of the sun. Its diameter can be calculated to be eight miles. A black hole containing 20 times the sun's mass is 75 miles across, and one with 10 million solar masses (that may be lurking at the center of the Milky Way galaxy) would be about 35 million miles in diameter. Everything within these limits swirls in and is crushed smaller than the diameter of the nucleus of a hydrogen atom. What happens after that is the big question. One possibility is that matter pulled into a black hole — that disappears forever from our universe — is somehow recycled and pumped back into the universe at a different place, at a different time, or perhaps at the same place but at a different time.

Time is distorted beyond meaning in a black hole. That's because space is crushed to infinitely small proportions so time becomes infinite too. In effect, both space and time have no meaning, at least in the sense we experience them. It is certainly not defying the bizarre aspect of these cos-



The creation of black holes can be seen from across millions of light-years. The normal appearance of the ninth magnitude spiral galaxy NGC-4725 is shown at the top. At right the arrow indicates the supernova blast that was observed from Earth in 1940. When a star goes supernova it increases up to 100 million times its former brightness. It then becomes easily visible from vast distances. A supernova marks the death of a star and the birth of either a neutron star or black hole.

Hale Observatories Photograph

mic whirlpools to assume a different time as a possible emerging point for the lost matter. This would be a wild theory if it were not for the fact that there are objects in the universe that look like the reverse of black holes — yes, you guessed it, white holes.

Where and what is a white hole? A quasar could be one. So far, quasars have no satisfactory explanation. They are small, just a little larger than the solar system in size (most of them anyway), and yet they release more energy than an entire galaxy of stars. Quasars make the sun seem totally insignificant by comparison. The nearest quasar is 1.5 billion light-years away; yet it shines as bright as a nearby galaxy and can be seen in an eight inch telescope. The most distant quasars are farther away than the most remote galaxies that we can observe. Their incredible brightness allows us to see them at these distances. Where does their energy come from? No physical process known can account for it except possibly one — the reverse of a black hole. Matter coming into our universe from nowhere; matter seemingly created from a point where nothing existed before!

Perhaps somewhere, sometime in the past or future an entire galaxy is being swallowed up by a black hole. The black hole gets larger as more material plunges into it, and as it gets larger its gravitational influence increases and pulls more and more material into it. The quasar pumps energy out in prodigious quantities as if its source was inexhaustible. One explanation for its energy might be that the matter and energy is coming out in the same way that it went into the mighty black hole.

When all of the matter that went into the hole in some other space and time is ejected out the white hole to produce a quasar, perhaps then it begins to settle down. Matter, flung out in all directions from a white hole, gradually forms a relatively stable object that under its own momentum is rotating and gradually forms into a disk. Finally it stabilizes. Within the disk blobs of matter collect under the influence of mutual gravitation. Discrete clouds or nebulae develop and within them stars are born. Have we witnessed the creation of a galaxy? Is this the evolution of the objects within our universe? Is there a continual creation as black holes swallow up matter from our universe and pump it into another universe or back into our own? Is our universe being created from the tombstones of others? As yet the link between black holes and quasars is strictly speculation or, at best, speculative theory.

But these questions will not remain in limbo forever. John A. Wheeler of Princeton University,

a leading black hole theorist, believes the answers lie in "relating relativity theory to quantum theory — connecting the laws of the universe at large with the laws governing the particles". This would unite all known physical laws into one grand scheme. So far no one has been able to develop such an encompassing theory.

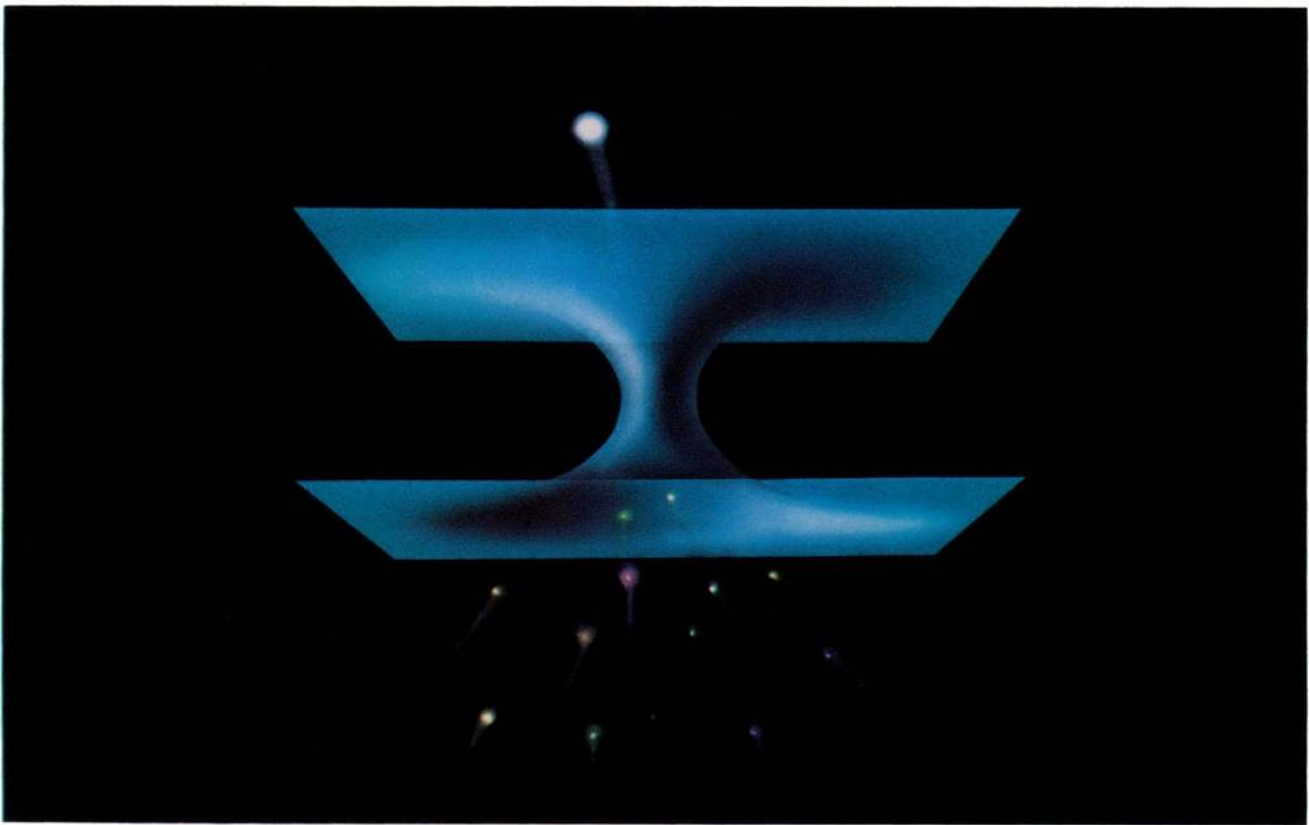
Caltech's Kip Thorne believes the answer is not around the corner. "I'm not optimistic that we will have an answer in less than 10 years," he said. "It's rather remarkable that we can say as much as we can about black holes."

Due to recent work by a young, dynamic group of English mathematicians, we are now at the point where we can make definitive statements about the exteriors of black holes without any fear of being wrong unless Einstein was wrong in his original theory of gravity. "Unfortunately," remarked Thorne, "we don't have such techniques for solving Einstein's equations and finding out what happens to the matter inside a hole."

"The most likely possibility," continued Thorne, "is that when matter gets deep inside a hole it becomes so badly crushed by intense gravitational forces down there, that it loses all organized information about its original structure. Protons are destroyed, electrons are destroyed — everything is crushed into a state of very high density where we don't today know the laws of physics." Most theorists would like to believe that somehow the matter remains even though the form of its organization — atoms, molecules, elementary particles — is destroyed.

Although most of the matter entering a black hole seems to be crushed out of this universe, there are conditions where certain trips through a black hole might be a gateway to another universe — but without the atom-crushing plunge through the hole's core. The space-warp so often talked about by science fiction writers may not be fiction.

The new ideas center around a very simple assumption. Everything rotates in the universe. Planets rotate, stars rotate, galaxies rotate, possibly the entire universe rotates — and this rotation must be taken into account if we are to understand such objects as black holes. Original calculations on the nature of a black hole had to assume that the initial star was not rotating but was spherical and collapsed in a uniform manner when it was crushed out of existence by the weight of the material on top of it. The theory proved that gravity can overwhelm all other forces to zap a star, or anything else that follows it, from the universe. However new calculations by a brilliant team of theoreticians have shown what happens when a rotating star collapses. Since



Artwork by Victor Costanzo

Matter plunging into a giant black hole in another universe may be linked to a quasar in our own universe. Since known laws of physics cannot account for the energy output of

quasars nor predict the fate of matter falling into the gravitational whirlpool of a black hole, there is no way at present to confirm this theory.

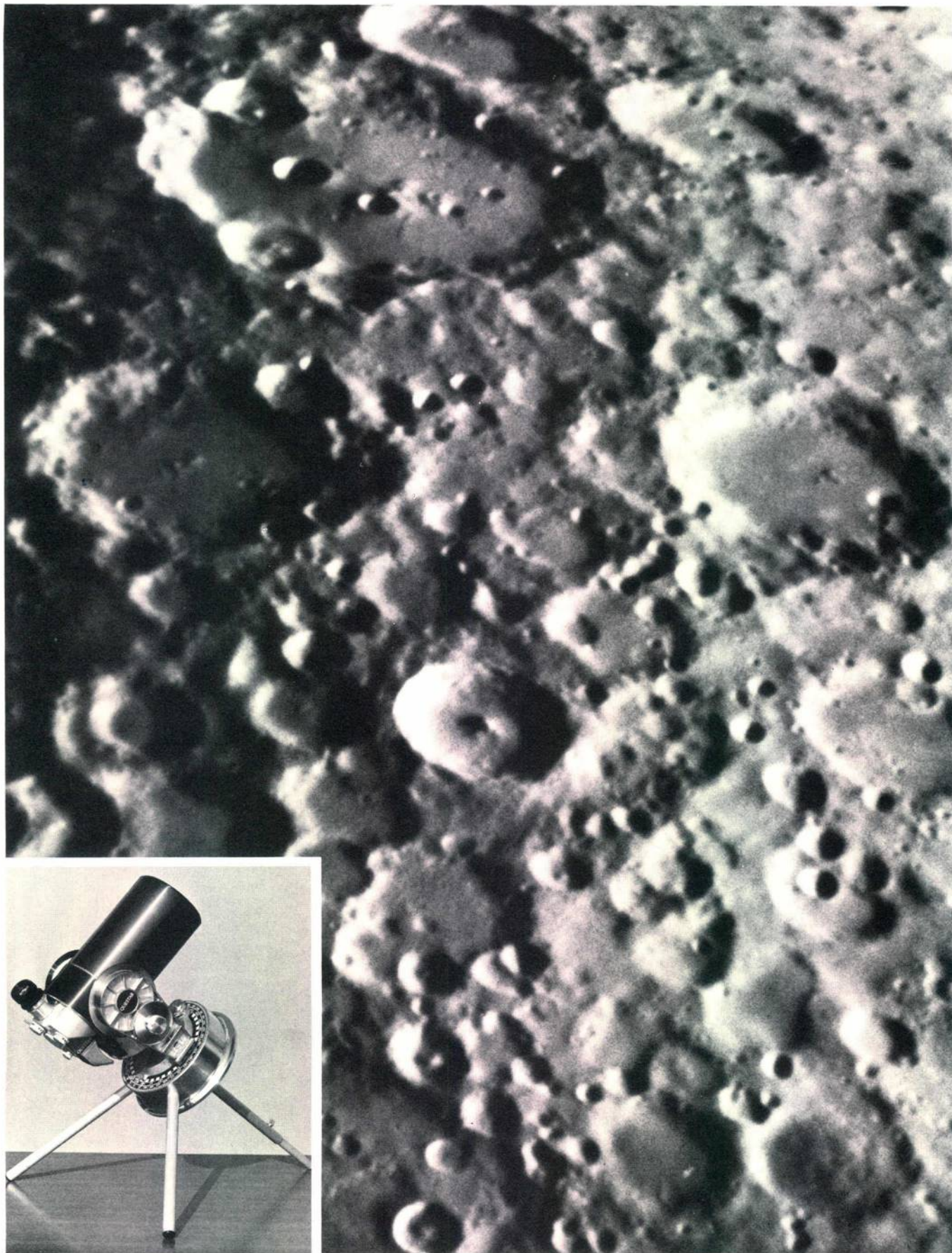
all stars rotate this brings us closer to reality.

During the collapse, as the star gets smaller, rotation increases just as a figure skater can increase her rotation in a spin when she pulls her arms toward her body. When a black hole begins to form, rotation speeds up to an incredible rate. In so doing it distorts the black hole so that it has two "surfaces" or event horizons. Just how the two event horizons actually form is buried in equations that transcend description here. But their theoretical existence provides fuel for mind boggling speculation.

Let's assume we have a future space traveller sitting at the control console of a spacecraft whizzing through space at nearly the velocity of light. A black hole looms ahead; its mass, dimensions and position are well known to our voyager of the distant future. He has purposely selected a large hole, millions of miles wide, so that the forces at its "surface" are not intense enough to damage his ship. He very carefully targets his spacecraft to plunge at a precise point somewhere between the inner and outer event horizons. According to modern black hole theory our traveller will be ejected into another universe! Perhaps by that time theoreticians will have mapped the

parts of the space-warp zone that can send the space traveller to a specific place in another universe. Once there, he could enter another black hole to fling himself back into our universe at a different time and place from whence he began!

In theory then, it is possible to escape from this universe into another by using the tremendous warp of the gravitational black hole. Of course the details of the voyage described here are truly speculative and may indeed never occur. But throughout the past so many of the dreams of science fiction writers have become the fact of tomorrow. Perhaps the most fanciful but useful of all these dreams, the space-warp — the ability to travel to a different time across countless light-years — will actually be possible. Instead of traversing those distances, the time and space-warping effects of the crushing gravitational forces around a black hole will be the slingshot of the future. The links between the past and the future, between our universe and others, are at last within the bounds of theory. As Arthur C. Clark, perhaps the greatest science fiction author of our time, once said "The only way of discovering the limits of the possible is to venture past them into the impossible." 🚀



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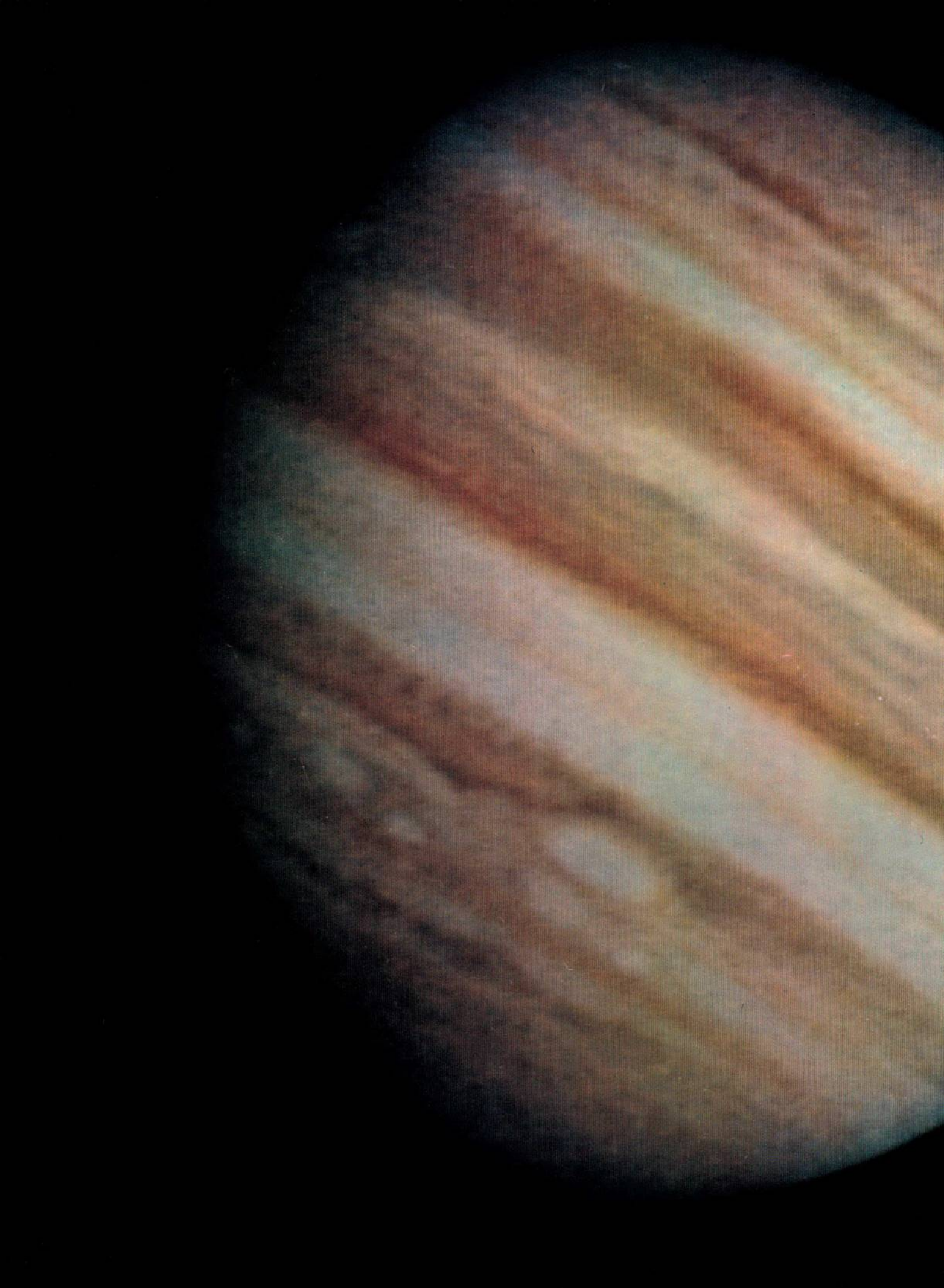
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jupiter

Pioneer 10 Photo of the giant planet reveals details never before seen.

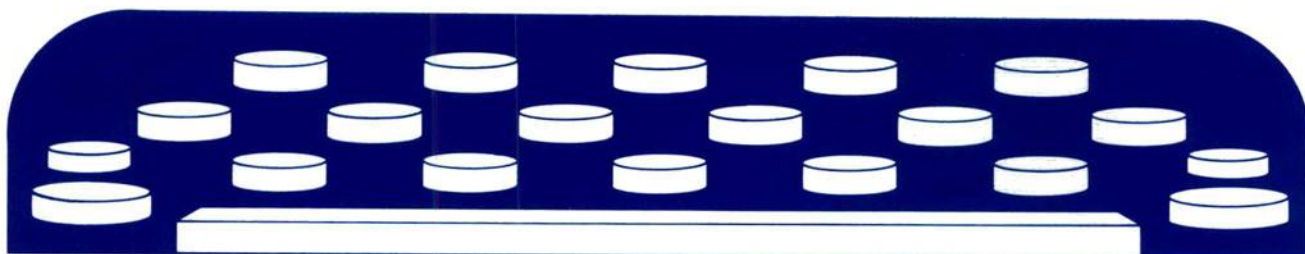
The ocean of clouds that makes up the visible surface of the planet Jupiter is shown in greater detail in the picture on the facing page than has ever been seen before. No telescope on the surface of the planet Earth, no matter how powerful, no matter how steady the atmosphere above it, has ever resolved such intricate lacing in the clouds of the multicolored planet.

Pioneer 10 was 1,255,000 miles from Jupiter when this picture was taken on Dec. 2, 1973; closest approach to Jupiter was still 29-1/2 hours away.

This photograph is a rectified view of the planet, and has been improved by computer processing of the raw picture data. This processing is necessary because of spacecraft speed on its trajectory, planet rotation at 20,000 m.p.h., constantly changing camera angles, and other factors.

In this view, the belts appear to become split up into detailed flow patterns within Jupiter's atmosphere and clouds. These detailed structures include wispy structures not necessarily parallel to the belts and zones. The oval clouds, which resemble the Great Red Spot but are smaller and whitish in color, have been known to exist for many years, particularly in the southern hemisphere (lower part of the picture). The smaller ovals are about the size of the continent of Asia. Jupiter is the solar system's largest planet with over 1,000 times Earth's volume. Its banded appearance is obvious when viewed through even the smallest telescopes. But the detail seen in this remarkable photograph was only suspected until now. University of Arizona scientists are now working on rectifying and enhancing other views of Jupiter taken at closer range by Pioneer 10.

NASA Photograph



IN FOCUS

Sir / I have found Thomas C. Bretl's mention of the differing appearances of the shadow transits of Jupiter's satellites fascinating since they agree closely with my own observations. I began observing Jupiter regularly with my 4-1/4 inch reflector during the summer of 1972, and first noticed the difference in Io's and Ganymede's shadow (and soon afterwards Europa's) after logging about 11 hours of observation.

However, on Aug. 22, 1973, at 11:15 p.m. EDT I noticed a black spot in the north equatorial belt not far from the eastern limb. At first I thought that Ganymede's shadow was in transit, but only one moon was west of the planet, and from my previous transit observations the satellite's separation seemed too great.

After checking the ephemeris I found that it was not a shadow, but Callisto itself which was in transit! Is the contrast between Callisto and Jupiter so much as to make the satellite appear black? Unfortunately, clouds prevented my viewing the entire event.

WILLIAM G. DILLON
Springfield, Va.

Mr. Dillon / Callisto is by far the darkest of Jupiter's moons, reflecting only 20 percent of the sun's light back into space. The other moons are more than twice this reflective, much more like the clouds of Jupiter. So Callisto, in contrast with the clouds of Jupiter, appears dark, but not as dark as a satellite shadow.

Sir / I have received your magazine since it was first published in August, 1973, and consider it the best magazine I have ever read. I must admit I look forward to Sky Almanac more than any other section as it gives the exact location of planets and asteroids.

Without your magazine I never could have seen Comet Kohoutek in its early stages.

Because of streetlights I couldn't use my telescope, so I couldn't take pictures of it. But it was visible in binoculars as a fuzzy star with a small, dim trail — right where you said it would be.

ROBERT A. GAULT
Eminence, Ky.

Sir / I must compliment you on the article "It's Simple to Photograph Constellations" in the November issue.

For all my photographs with my Minolta SRT-101, I used Tri-X film at ASA 400. I started with 15 second exposures and increased to 15 minute exposures for trailing. On some I used eight second exposures to show only the brightest stars. On Nov. 23, I was lucky enough to photograph a meteor shower as I was taking a 15 minute exposure.

I wasn't sure what the results would be, so instead of developing the film myself, I had a professional photography shop develop the Tri-X in Microdol-X, 3:1 at 70 degrees Fahrenheit for 17 minutes. When my negatives were printed, I couldn't believe the fantastic results!

DARRELL NORTHCUTT
Knoxville, Tenn.

Sir / Your magazine is a wonderful aid in getting kids interest in astronomy. I wish it had been around 15 years ago.

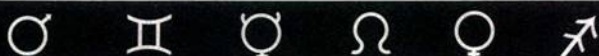
ROBERT SCHIFFER
New Orleans, La.

Sir / I'm 14 years old and I've been reading ASTRONOMY since the first copy came out. Your magazine was very helpful to me in finding Jupiter's moons last summer. The article on Comet Kohoutek in the October 1973 issue was great too, including the beautiful picture by Victor Costanzo. I never saw Comet Kohoutek so I'll just have to wait until Halley's comet comes around in 1986.

On Feb. 1 when I was getting ready for school I saw Venus around 7:15 a.m. I thought it was an airplane so I didn't think much of it, but when I came back around 7:30 it was still there. I got out my telescope and sure enough it was the beautiful crescent!

Recently I have been looking at Saturn and the Orion nebula. In my three inch reflector the Orion nebula looks like nothing, compared to the one on the Orion Calendar.

GWEN WANKOW
Somerville, N.J.



ASTRONOMY

Index to Vol. 1

In response to requests from our readers and schools, ASTRONOMY has just published a cumulative index to Vol. 1. This subject index covers August, September, October, November and December, 1973, which includes issue Nos. 1 through 5. Index to Vol. 1 is available for \$1.00 each, including handling and first class postage.

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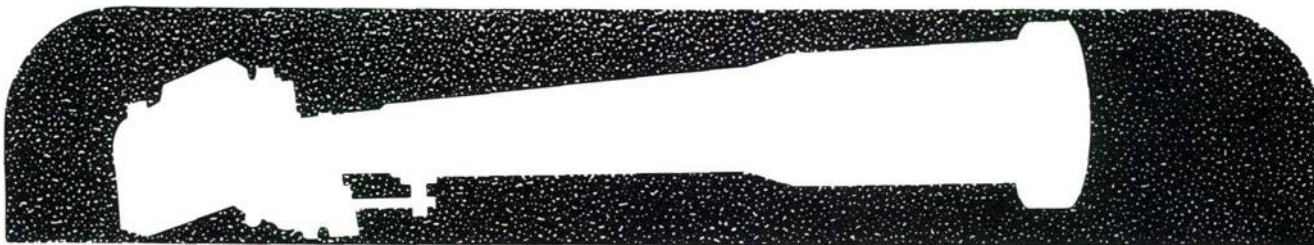
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Jan. 8, 1974

Photograph by J. D. Kousbaugh



PHOTOGRAPHY IN ASTRONOMY

Comet Kohoutek Pictorial

Although Comet Kohoutek did not live up to its billing as "comet of the century", it certainly provided astrophotographers with a challenging but rewarding target for their cameras. Anything from a tripod-mounted camera without any special lens or additional equipment, to the 48 inch Schmidt photographic telescope on Mt. Palomar was used to obtain the photographs on these pages.

The comet was only barely visible to the unaided eye throughout its sweep past both Earth and the sun. When it was at its brightest on Jan. 1 and 2, it was so close to the horizon that hardly anyone saw it. Last month's ASTRONOMY fea-

tured a photo taken Jan. 3; in the portfolio on these pages are many pictures spanning the prime observing period, Jan. 5 through 19.

On the opposite page is a stunning 10 second exposure taken from the summit of the 1700 foot Green Mountain, 15 miles west of Bremerton, Wash. on Jan. 8. A Minolta SRT-101, 55mm f/1.7 was strapped to the tube of a three inch refractor for the exposure. Jupiter is below and to the left, and Venus is shining through one of the pine trees at the mountaintop. The stars of Capricornus and Aquarius are surrounding the comet. Immediately to the right of the comet's head is Nu Aquarii (magnitude 4.5). The bright star at the center of the



Jan. 16, 1974

Photograph © by Donald D. Woodman



Jan. 10, 1974

Photograph by Ronald V. Smith

upper portion of the photograph is Beta Aquarii (magnitude 3.1). Most observers thought it was fainter than Beta on this date. A photo taken at virtually the same time is the upper of two on page 27, taken on GAF 500 film from Whitewater, Calif.

Three days earlier, this time from Tacoma, Wash., the color shot below was captured. It's a 10 second exposure on Kodak 5254 film "pushed" to ASA 400. A tripod mounted Canon FD with a 50mm f/1.8 lens was used. Venus is the brilliant object to the left of the comet's tail. Jupiter is slightly higher and farther left. The comet's tail is at least five degrees long, although to the unaided eye it appeared to many observers to be half that length. The horizontal lines of stars in the upper part of the photo are aircraft lights.

Another early January photo, at lower left on page 30, is a telephoto view showing a sixth magnitude star shining through the gossamer tail of Comet Kohoutek. A 400mm f/6.3 lens/camera combination was attached to an eight inch Celestron for guiding. Exposure time was 2 minutes 40 seconds on High Speed Ektachrome, taken near Birmingham, Ala. Venus is the brilliant object at lower left.

Another telephoto shot on page 30 (top) is



Jan. 5, 1974

Photograph by Steve Mackey



Jan. 8, 1974

Photograph © by Patrick Michaud



Jan. 14, 1974

Photograph by Marvin J. Mayo



Jan. 15, 1974

Hale Observatories Photograph



Jan. 10, 1974

Lowell Observatory Photograph

also a Jan. 8 view. Nu Aquarii is the modestly bright star immediately left of the comet, and Venus is to the lower left. Stars up to eighth magnitude are shown in this one minute exposure on GAF 500 film. A 200mm lens/camera arrangement was used for this guided photograph. For all photos over 10 seconds in length the camera must be attached to an equatorially mounted telescope which, in turn, is used as a high power guide scope.

Two Jan. 10 portraits of Comet Kohoutek (page 26, top and page 30, bottom right) are both five minute exposures on High Speed Ektachrome taken by California astrophotographers.

Also on Jan. 10, professional astronomer Henry Giclas used the 13 inch photographic refractor at Lowell Observatory, Flagstaff, Ariz., for an eight minute exposure (page 28, right). Giclas guided the telescope on the head of the comet which caused the stars to drift a small amount.

Jan. 14, 1974 Hale Observatories Photograph →





Jan. 8, 1974

Photograph by Laurens K. Thurman



Jan. 7, 1974

Photograph by Conrad Kussner



Jan. 10, 1974

Photograph by Hal Jandorf



Jan. 19, 1974

Photograph by Jack Newton



Dec. 13, 1973

Photograph by Kenneth L. Mason



Jan. 15, 1974

Photograph by Marvin J. Mayo

Two excellent photographs were obtained on successive evenings (pages 27 and 31) with a 135mm telephoto and High Speed Ektachrome film. The Jan. 14 picture was a one minute exposure, while the Jan. 15 shot (which includes a passing aircraft's beacon) was 30 seconds.

On the same evenings the big 48 inch Schmidt photographic telescope was used for the spectacular photos on page 28 (left) and page 29. Each was a three minute exposure on film sensitive to blue light to bring out details in the gas tail.

A rare meteor trail passing in front of the

comet was caught during a two minute exposure with an eight inch Schmidt camera, f/1.5, on Plus-X film at La Plume, Pa. (this page).

Comet Kohoutek was viewed from near Sunspot, N.M. on Jan. 16 (page 25). The photo is a seven minute exposure on Tri-X 4 x 5 inch film with a 500mm f/5.5 lens.

As the comet began to fade, a six minute exposure on Tri-X film was obtained near Toronto, Canada with a 12-1/2 inch telescope. The photo (this page) shows some of the wisps of the gas tail evident in the observatory photos. ☛

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α Alpha	η Eta	ν Nu	τ Tau
β Beta	θ Theta	ξ Xi	υ Upsilon
γ Gamma	ι Iota	$\omicron$ Omicron	ϕ Phi
δ Delta	κ Kappa	π Pi	χ Chi
ϵ Epsilon	λ Lambda	ρ Rho	ψ Psi
ζ Zeta	μ Mu	σ Sigma	ω Omega

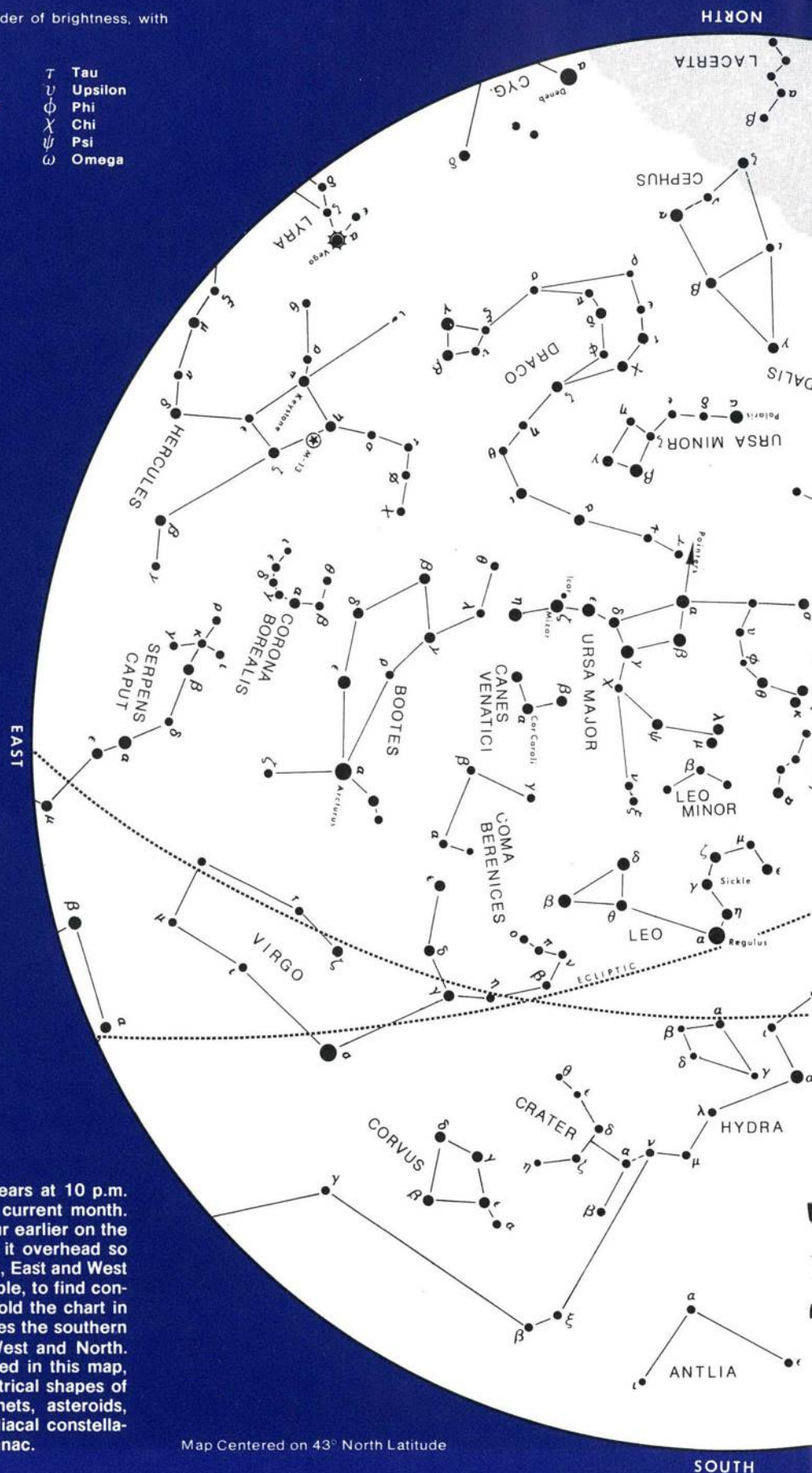
MAGNITUDES

- ☉ Zero
- First
- Second
- Third
- Fourth
- Fifth

OBJECTS

- ★ Open Clusters
- ⊙ Globular Clusters
- Diffuse Nebulae
- ☾ Galaxies
- Double Stars
- Variable Stars

Star Dome approximates the sky as it appears at 10 p.m. Local Daylight Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder in Sky Almanac.



Map Centered on 43° North Latitude

STAR DOME



The brilliant stars that were with us all winter — Orion, Taurus, and their companions — are now low in the west at chart time and by the end of the month will be disappearing into the dusk. The spring stars are now well in view. To a novice astronomy enthusiast the terms “spring stars” or “winter stars” can be confusing.

“Spring stars” refers to those that are seen in the northern hemisphere in the evening during the spring season. The major constellations identified with spring are Leo, Virgo and Bootes (pronounced bow-OH-teez). However around these constellations are less brilliant, often inconspicuous, groupings that are ideal for constellation hunters on a warm spring evening.

Of course the first task is to become oriented to the major groups. First locate the Big Dipper and imagine its bowl is filled with water. If holes were punched in the bottom of the bowl, the Big Dipper would drain to the south and spill right on top of Leo the Lion.

Leo is fairly conspicuous, consisting of two shapes outlined by reasonably bright stars. One of these is a backwards question mark with the dot of the question mark at Regulus. This configuration is sometimes called the “sickle” because of its resemblance to that tool. East of the sickle is a triangle of stars, and together they form the lion — the triangle being his hindquarters and the upper part of the sickle marking his head. Regulus is his chest or paws. Leo is one of the few constellations that even remotely resembles

what it was named for.

Continuing south from the Big Dipper through Leo we encounter the only bright star in a vast area of the southern sky that seems empty at this time of year. That star is Alphard — the only bright light in an undistinguished straggly constellation called Hydra the Serpent. The head of the beast is a little circle of stars below the zodiac constellation Cancer. From there the serpent twines its way 100 degrees across the sky. It really doesn't matter if you can't follow the line of faint stars that makes up Hydra. It doesn't point to any other constellations of significance. So really just identifying the head and Alphard is enough.

The fact that Hydra has only one head goes against the legends surrounding this terrible monster. The creature supposedly had a number of heads that conveniently, when cut off, were replaced by two. Hercules and his nephew Iolaus went hunting the monster one day and found out how to get rid of the heads. Hercules lopped them off and Iolaus sealed the wound with a hot iron before the other heads could emerge. However the central head of the monster was supposed to be immortal (perhaps this is the one shown among the stars), but Hercules eventually took care of it by burying it under a rock.

An annoying thing that Hercules had to contend with while battling with the serpent was a crab that kept pecking away at his ankles. Hercules took time out from chopping the heads off Hydra to squash the crab with his foot and toss it aside. Now the crab sits above Hydra's head as the constellation Cancer.

The serpentine nature of the constellation as it appears among the stars led Egyptians to imagine that this constellation was the heavenly counterpart of the Nile river. The celestial appearance of Hydra is somewhat similar to Draco, the constellation that twists around the Little Dipper, which is also appropriately a serpent. Draco is more easily seen later in the year. The ancient Chinese perhaps noted the reddish color of Alphard by making it the prominent star of the "red bird" that combined their seven lunar divisions of the southern quarter of the heavens. This and other Chinese groupings disappeared from sky mythology centuries ago.

Alphard appropriately means the "solitary one in the serpent" when translated from Arabic. It is an orange giant star similar to Aldebaran and Arcturus, but farther away at 95 light-years. Its color contrasts with the brilliant blue-white of Regulus and is especially noticeable in binoculars. 

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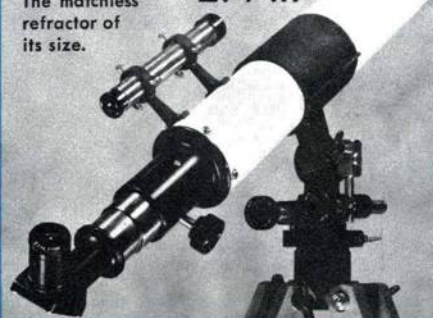


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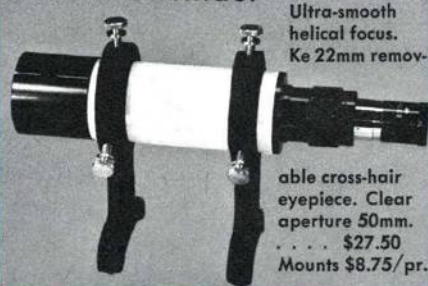
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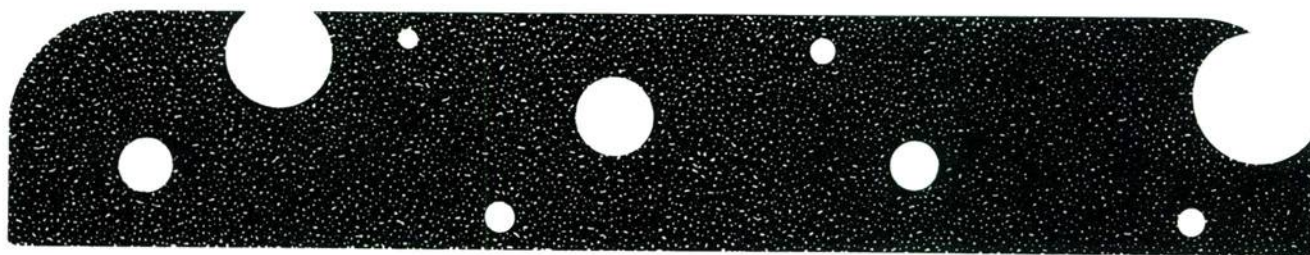
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STELLAR FRONTIERS

Between The Stars

by
Gerrit L. Verschuur

"Surely these are holes in the heavens!" At least that's what William Herschel thought when he trained his telescope on dark areas in the Milky Way that appeared to be devoid of stars, 200 years ago.

In 1909 E.E. Barnard, the best known observer of these "holes", finally accepted the fact that they were not holes at all but obscuring clouds of matter that blocked the light from more distant stars. Soon other astronomers accepted the notion that clouds of dust exist in interstellar space. But what are these clouds and where do they come from?

Photographs of nebulae almost always reveal the presence of dust clouds, and even the naked eye can detect dark lanes running through the Milky Way in Cygnus. These dark lanes are enormous clouds of interstellar dust. The presence of dust in interstellar space is a hindrance to astronomy in the sense that it prevents us from seeing very far into space along most of the Milky Way. In some directions we can only see 1,000 light-years away, but in others — like into the spiral arm in the constellation Carina in the southern hemisphere — it is believed that we can see for some 30,000 light-years at least. For some reason Carina is very clear of dust. (Dust clouds contain a lot of gas, but not all interstellar gas clouds contain dust.) Some clouds, like those in Cygnus, are very large and diffuse; others are small and dense, allowing no starlight at all to pass through them. These smaller clouds are

proving to be particularly interesting in light of recent research. They can range from small fractions of a light-year across to many light-years in diameter, and can absorb from 2 to 10 magnitudes of light from a star that appears to be behind them.

Today it is believed that many of the smaller clouds, called globules, are in fact very dense clouds of matter collapsing to form stars. From optical observations of absorption of starlight we know that sodium and calcium atoms exist in the dust. And by radio astronomical techniques, many different atoms and molecules have been found to reside inside these clouds. Because molecules are found in the clouds, it means that the clouds are actually opaque and that much of the radiation from space, which could destroy the molecules, is being effectively kept out. This, in turn, means that the density of dust particles is therefore large enough so as to absorb all the light and ultraviolet radiation. It's something like a rifle being fired into a dense forest. Before it travels very far the bullet will lodge in a tree.

A stellar incubator composed of dust and gas forms a wreath around a newly created cluster of stars. Called the Rosette nebula, this gigantic cloud is 55 light-years wide and 2,600 light-years distant. The dark knots and globules silhouetted against the bright nebula are dense dust clouds that will ultimately condense into stars. Recent calculations indicate 11,000 stars the mass of our sun could be formed from this nebula.

Photograph Copyright California Institute of Technology and the Carnegie Institute of Washington





Hale Observatories Photograph

So it is with radiation entering one of these globules.

By astronomical standards these black clouds are dense — up to a million atoms or molecules per cubic centimeter. This compares with only one to ten per cubic centimeter in average interstellar clouds. Bear in mind that the best vacuums created in earthly laboratories cannot even get down to the densities of these densest dust clouds. This makes experiments attempting to precisely duplicate conditions in dust clouds impossible to perform. This, in turn, means that astronomers have to do some very sophisticated, and therefore often incorrect, guessing as to the nature of the dust particles themselves.

The dust particles are known to be very small, probably about 0.00001 inches in diameter and about as reflective as snow. This is inferred from the way they actually absorb light at different wavelengths. They are believed to be elongated so that they can produce polarization of starlight. Some astronomers think the dust particles are graphite covered with a layer of ice; some want silicon as the basic constituent; some have suggested that small diamonds would do the trick — the trick being to explain the observed effects of the dust on starlight. Interestingly enough, while we might not be certain of the precise nature of the dust particles themselves, we can nevertheless go ahead and learn other useful things about the clouds. For example, where do they come from?

It is generally believed that the dust is produced in the atmospheres of giant stars. To examine this we will step back to an earlier stage of the evolution of the universe. The first stars that were born grew out of gas clouds with no dust in them. (Let's forget for the moment the theoretical problems associated with the cooling and contraction of such clouds in the absence of dust.) During certain stages in their evolution these stars become bloated and unstable, forming complicated molecules in their atmospheres and then puffing them off into space. These stars are effectively generators of the dust particles. We know this to be true since we can observe strong stellar winds blowing away from many giant stars and we can recognize the presence of the material in these winds by its absorption of the star's normal light. Therefore, as the galaxy evolves, the interstellar medium gathers an increasing amount of dust from these stars. There seems to be enough of the right kind of giant, cool stars

to have produced the clouds we see, so this scenario of dust formation is probably correct.

The newly formed dust clouds are ideal places to build molecules, many of which are needed to form life on planets. So as the universe evolves, molecules of increasing complexity are capable of being formed and, more importantly, capable of being preserved within the dust clouds. We also know that many of the globules are presently regions of star formation and today it is a source of endless discussion as to how many of the molecules found there (such as water, formaldehyde, ammonia, carbon monoxide and hydrogen cyanide) might survive the star birth process and remain in the surrounding nebula that will form planets. This is a fascinating question because the molecules are precisely the ones that were needed for biological structures (fatty acids, amino acids) to evolve on primitive Earth.

The globules therefore are the state of matter just before star formation. Because they are dark and cold (often only a few degrees above absolute zero), the pressure of hotter surrounding matter on their outer surfaces tends to cause contraction, thus increasing the density. Eventually the density reaches the point where individual stars, and presumably planetary systems, emerge. Many stars and planets could be formed because the amount of matter in a typical cloud is considerable despite its low density. Often globules are several light-years across and contain enough matter to give birth to many thousands of stars like the sun.

Let us look a little more closely at what occurs inside dense dust clouds. If we accept the fact that there are small dust particles in the clouds, then we can use these to construct additional molecules in the following manner. Take two atoms and call them X and Y. We want to make the molecule XY. One way we can do it is to simply wait till X and Y collide by chance in the cloud. Of course the denser the cloud, the more likely this is to happen. On the other hand, X can bump into a dust grain which is much larger than X or Y, and stick to it. Then later, Y does the same and they unite on the surface of the grain to form XY. But astronomers would not be able to observe the true nature of XY, or even its presence, if it stayed stuck to the grain. Somehow it has to get loose again so that it can float off and join up with all the other XYs, before we can detect it. To get it unstuck we have to give it a little energy. But then we find that not only do we free XY, we also break XY up into X and Y separately again! This problem is a serious one which prevents an easy explanation for the existence of molecules in dust clouds. Even when the

This close-up view of part of the Rosette nebula shows dark globules, both large and small. The smallest visible are about one trillion miles across — about 100 times the diameter of Pluto's orbit.



Steward Observatory Photograph

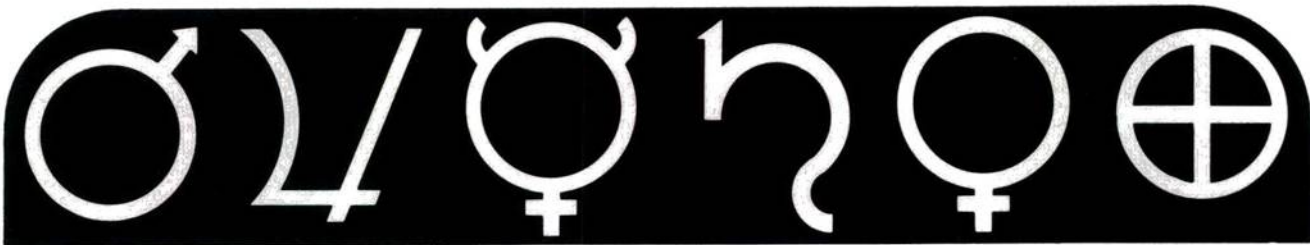
One of William Herschel's "holes in the heavens" should not be confused with a black hole. This "hole", known as Barnard 335, is a several light-year wide cloud of dust and gas in the constellation Aquila. It looks like a hole because it

blocks light from the more distant stars behind it. When clouds like this appear in front of a bright nebula the result is spectacular, as seen in the great M-16 nebula on this month's cover.

average XY is found floating about in the cloud, radiation leaking into the cloud from outer space is sufficient to destroy a typical XY every 30 years. Yet the clouds are millions of years old, and still they are full of XY and other molecules. Why? There must be some molecule building occurring all the time to balance the destruction.

The processes required to build molecules in clouds are only just beginning to be understood. Such processes involve starting off with a carbon atom, shining light on it, ionizing it, making it collide with molecular hydrogen, shining more

light on it, and letting the resultant combinations collide with electrons, protons, and other atoms, etc., so as to allow many complex molecules to be built to counter their destruction. This theoretical examination of molecule building is now part of the new field of astro-chemistry which has emerged as a consequence of the recent detection of molecular clouds in the "holes in the heavens". It's a study in its infancy but it holds the promise of tying together stars, life and evolution — an awesome arena for the mind of man. 



SKY ALMANAC

Saturn and Mars Together in the Spring Sky

The highlight of the April sky is the conjunction — apparent close approach — of Saturn and Mars. Both planets appear in the constellation Taurus. Mars, the nearer planet but four times fainter than Saturn, moves more rapidly in its orbit and passes the ringed planet on April 20. The two planets will appear about three times the width of the moon apart on that date. Mars will be to the right (west) of Saturn prior to the 20th and to the left (east) of it after that date.

Saturn

In addition to its conjunction with Mars, Saturn remains the showpiece of the evening sky. At magnitude +0.3 all month its apparent size and distance also change little. On the 1st it is 856 million miles away and 18.1 seconds of arc in equatorial diameter. By the 30th the distance is 897 million miles and the diameter reduces to 17.3 seconds. The rings are still fully open with Cassini's gap easy to see in a four inch or larger telescope. Titan, Saturn's largest moon, can be

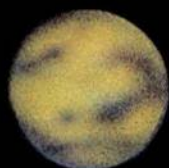
seen all during its 16 day orbit of the planet; for identification, look for it (with a two inch or larger telescope) exactly to the east of Saturn on May 1, and 17, and to the west on May 9 and 25. Titan should appear to be about five ring diameters from the planet at these times. (It appears closer when in front or behind Saturn between these dates.)

Mars

Now fainter than Aldebaran (which is just west of it) the red planet is magnitude +1.5 on the 1st fading to an inconspicuous +1.7 by month's end. Were it not for its interesting location near Saturn in the southwest evening sky this month, Mars would be easy to overlook. In the telescope the planet is of no interest as it dwindles from 5.4 to 4.7 seconds of arc in diameter. It is barely larger than distant Uranus. During April, Mars increases from 160 to 184 million miles from Earth.

Venus

The last 1-1/2 hours of the night contain

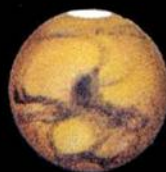


(A) MERCURY

April 1
R.A. 23^h06^m
DEC. -8° 04'
DIA. 6.5"
MAG. +0.2

(B) MERCURY

April 15
R.A. 0^h24^m
DEC. -0° 02'
DIA. 5.5"
MAG. -0.2



(C) MARS

April 1 15
R.A. 5^h12^m 5^h49^m
DEC. +24° 34' +24° 58'
DIA. 5.5" 5.0"
MAG. +1.4 +1.6



(D) CERES

April 1 15
R.A. 21^h54^m 22^h14^m
DEC. -19° 51' -18° 46'
MAG. 8.4 8.3



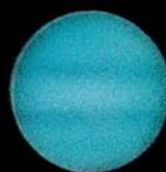
SUN

The sun is within the stippled zone throughout the month. Planets and stars in this area are not easily seen.



(L) SATURN

April 1 15
R.A. 5^h55^m 5^h59^m
DEC. +22° 40' +22° 42'
DIA. 16.2" 15.8"
MAG. +0.3 +0.3



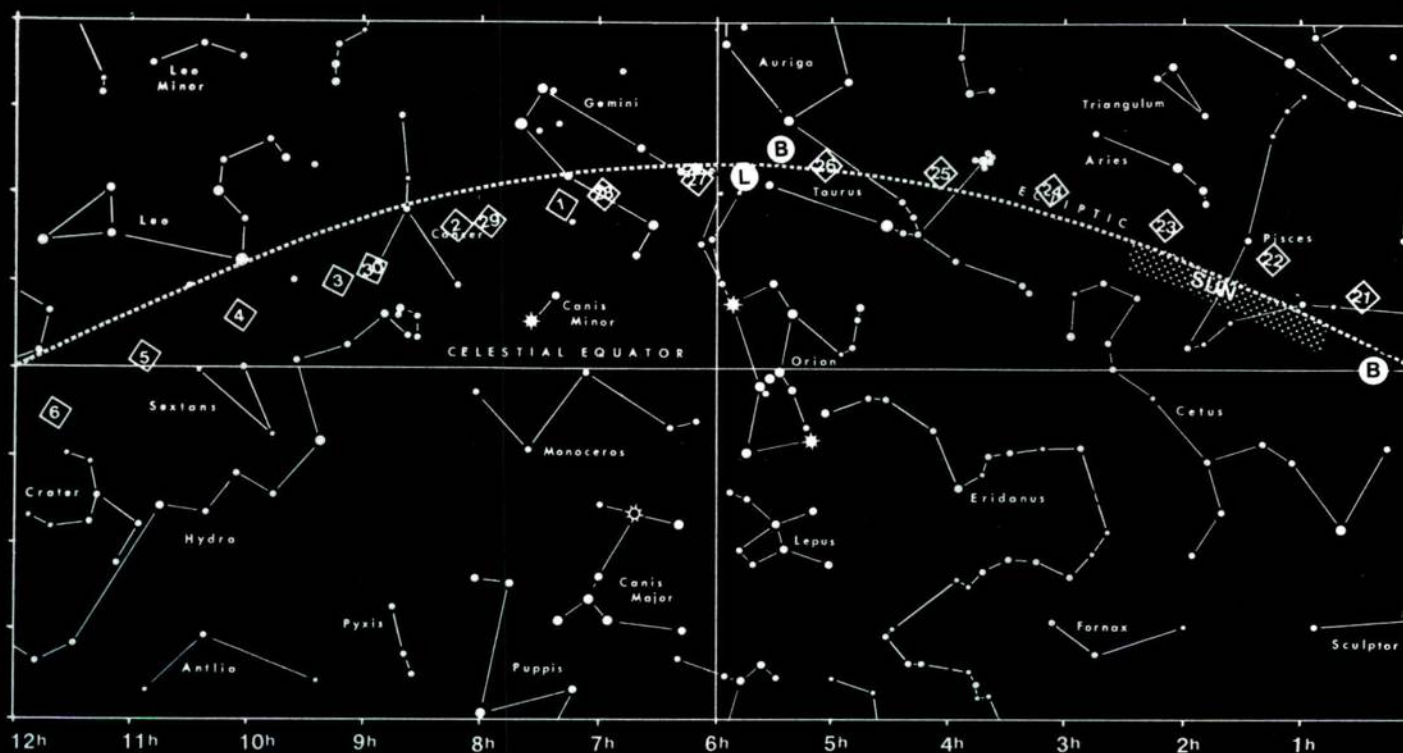
(M) URANUS

April 1 15
R.A. 13^h39^m 13^h37^m
DEC. -9° 37' -9° 24'
DIA. 3.92" 3.94"
MAG. +5.7 +5.7



(F) NEPTUNE

April 1 15
R.A. 16^h32^m 16^h32^m
DEC. -20° 17' -20° 15'
DIA. 2.46" 2.48"
MAG. +7.7 +7.7

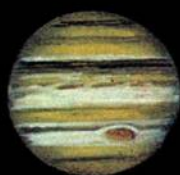


The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and DEC. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. MAG. = magnitude, a



(E) VESTA

April 1 15
 R.A. 12h57m 12h45m
 DEC. +7° 42' +8° 52'
 MAG. 5.8 5.8



(H) JUPITER

April 1 15
 R.A. 22h31m 22h41m
 DEC. -10° 16' -9° 17'
 DIA. 31.7" 32.5"
 MAG. -1.7 -1.7



(I) VENUS

April 1 15
 R.A. 21h45m 21h45m
 DEC. -11° 53' -11° 53'
 DIA. 25.5" 25.5"
 MAG. -4.0 -4.0

(J) VENUS

April 1 15
 R.A. 22h41m 22h41m
 DEC. -8° 14' -8° 14'
 DIA. 21.9" 21.9"
 MAG. -03.9 -03.9



(G) PLUTO

April 1 15
 R.A. 12h46m 12h45m
 DEC. +13° 47' +13° 54'
 MAG. +14 +14



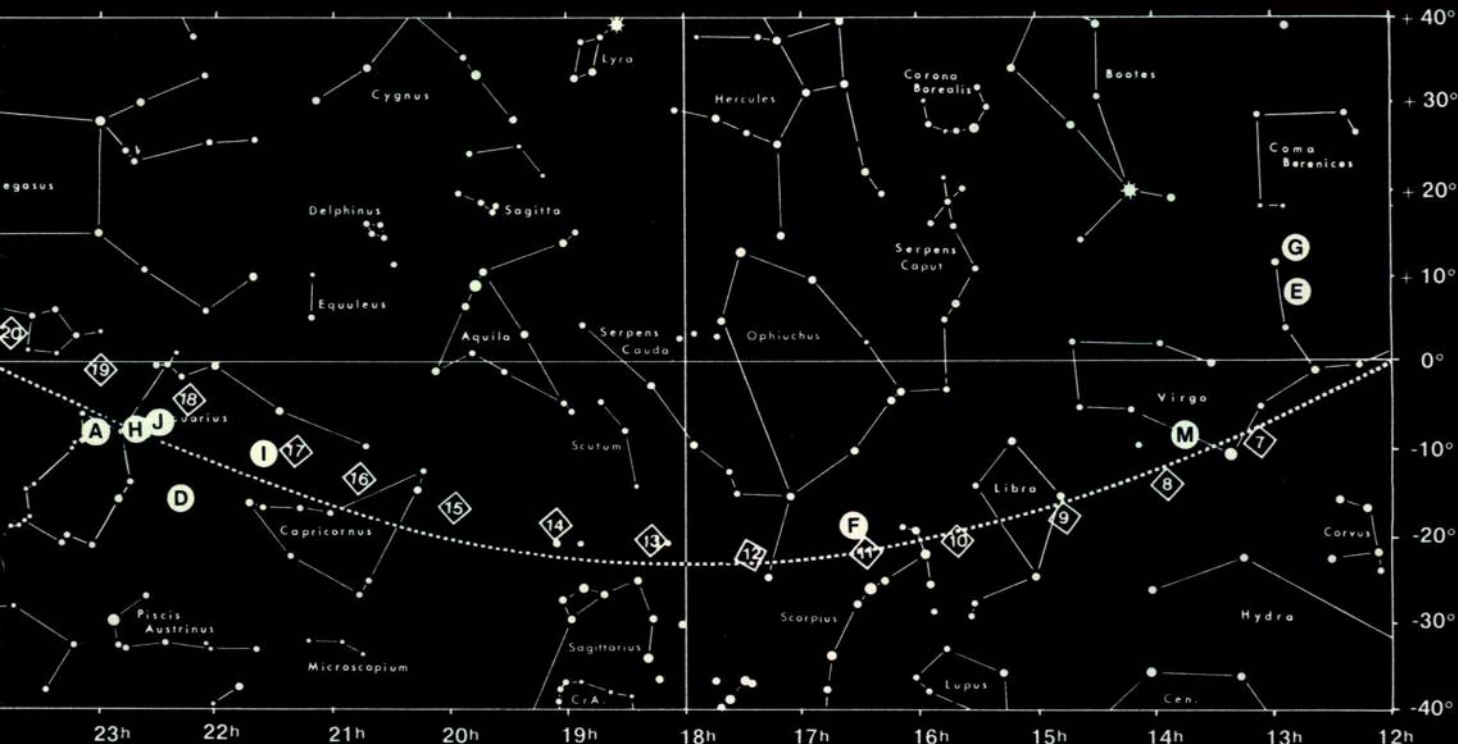
LAST QUARTER
 April 14



FULL MOON
 April 6



FIRST QUARTER
 April 29



measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) DIA. = the planet's apparent diameter in seconds of arc. The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th.

the most brilliant of the planets — Venus. At magnitude -4 it dominates the eastern morning sky. (Actual magnitude is -4.0 on the 1st fading slightly to -3.8 by the 30th.) Since nothing else in the sky apart from the sun and moon is nearly as brilliant as Venus, it can be easily mistaken for aircraft landing lights. Telescopically the planet's diameter diminishes from 25 to 19 seconds of arc during the month as its distance increases from 64 to 84 million miles in the same period. But its phase changes from nearly half (47 percent) on the 1st to a 61 percent illuminated visage on the 20th. For the rest of the year Venus' phase will slowly increase as it swings around to the far side of its orbit. But at the same time, the planet's diameter decreases resulting in more difficult viewing. Mariner 10's cloud pattern photography, discussed in *Astro-News* this month, is a significant new addition to our knowledge of our sister world.

Jupiter

Jupiter and Venus will be within a few degrees of each other from the 10th through the 20th, with Jupiter below and to the left of Venus through the morning of the 14th, and above and to the right after that date. The waning crescent moon joins this celestial waltz on the morning of the 18th when it will be less than 10 degrees from both planets. Weather permitting, astrophotographers might want to try recording this "get together".

Jupiter is not yet in convenient observing position even though it is quite bright at -1.7 magnitude. Distance during the month decreases from 539 to 508 million miles from Earth. The planet's equatorial diameter is 36.1 seconds by month's end — still not much compared to the 49.5 seconds we will be treated to late this summer. The chart of Jupiter's satellite positions will resume next month.

Mercury

The innermost planet is too near the sun for observation this month.

Uranus, Neptune and Pluto

As described in this month's *Gazer's Gazette*, these three planets are now within telescopic view. Uranus is nearest Earth on April 15 at 1.62 billion miles from us. It is 4.0 seconds in diameter — not much smaller than Mars, but much fainter at magnitude 5.7.

Neptune moves in from 2.83 to 2.80 billion miles during the month. It will be nearest Earth on May 30 at magnitude 7.7.

Pluto was officially nearest Earth on March 26 at 2.85 billion miles — only slightly farther than Neptune. By month's end its distance has increased to 2.91 billion miles, but it's so far away anyway that a few tens of millions of miles doesn't make any impact on its 14th magnitude

appearance.

Meteors

During the early morning hours of April 22 the annual Lyrid meteor shower might provide some meteors worth looking for if the weather is compatible with sitting outside for several hours. Normally after midnight, the vigilant observer will see six or seven meteors per hour. However this rate doubles the morning of the 22nd when most of the meteors will seem to originate from the constellation Lyra — hence the shower's name. If the moon was in the sky, this moderate meteor display would not be worth observing. But the moon is new, so conditions are favorable.

Chart Changes

Regular readers of *Sky Almanac* will notice a change in our monthly planet finder chart. We have changed the chart by adding some things and eliminating others in order to make it more useful. As for the things we've added: the position of the moon is now included for every day of the month. This is a convenience for several reasons. First, it shows when the moon is near a particular planet or constellation. It's difficult to observe a planet telescopically when the nearly full moon is fairly close to it. This is even more pronounced if deep sky work is contemplated. Additionally the chart shows you when the moon is in the vicinity of the sun and therefore not easily visible. It also shows how sometimes the moon is above the ecliptic and sometimes below. (The ecliptic is the plane of Earth's orbit and, in general, the path of the moon and planets. It precisely marks the path of the sun in the sky.)

A second major change is a band for the position of the sun during the month. Obviously this part of the sky will be rendered unobservable as far as the astronomy enthusiast is concerned. A further change is the inclusion of the positions of Mercury and Venus for the 1st and the 15th of the month. And finally, a system of letters for identification of the planets replaces the welter of dotted lines that formerly crisscrossed the chart.

It is hoped that these additions and changes will make the chart more useful for our readers. The few deletions that we made probably won't be noticed since there is more on the chart now than there used to be and, we think, in a more useful format. If you agree or disagree, we would like to hear from you. Your comments about these changes or other aspects of *ASTRONOMY* are always welcome.

While we're discussing changes and comments we remind you that the photos and drawings used in this and other departments usually come from our readers. Besides being properly credited, payment is made for each photo or drawing used. 

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by James Stanley Hey



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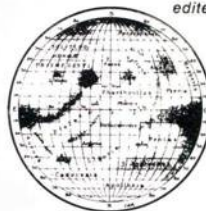
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GAZER'S GAZETTE

OBSERVING THE PLANETS BEYOND SATURN

Shining brilliantly on the border between the constellations Gemini and Orion is the planet Saturn. Nearly one billion miles from Earth, the planet and its system of rings are so large that they appear to the unaided eye as a zero magnitude star. The rings, when fully open as they are in 1974, raise the planet's brilliance to its highest level possible making it an unmistakable object with the unaided eye and a spectacular sight in the telescope.

But Saturn, as far as spectacle is concerned, is the end of the line in the solar system. Beyond it is a bleak 900 million mile gulf as wide as the distance Saturn is from the sun. Then, 1.8 billion miles from the sun is Uranus, the first of the outer planets. Because of its vast distance and its smaller size (compared to Jupiter or Saturn), Uranus appears as a very faint naked eye star from Earth. If the 29,200 mile wide Uranus was as large as the planet Jupiter, it would still only appear as a third magnitude star from Earth. The important factor is distance. But it's not so far that a small telescope will not show it as a planet. Any telescope three inches in aperture will reveal the small bluish-green disk of the seventh planet.

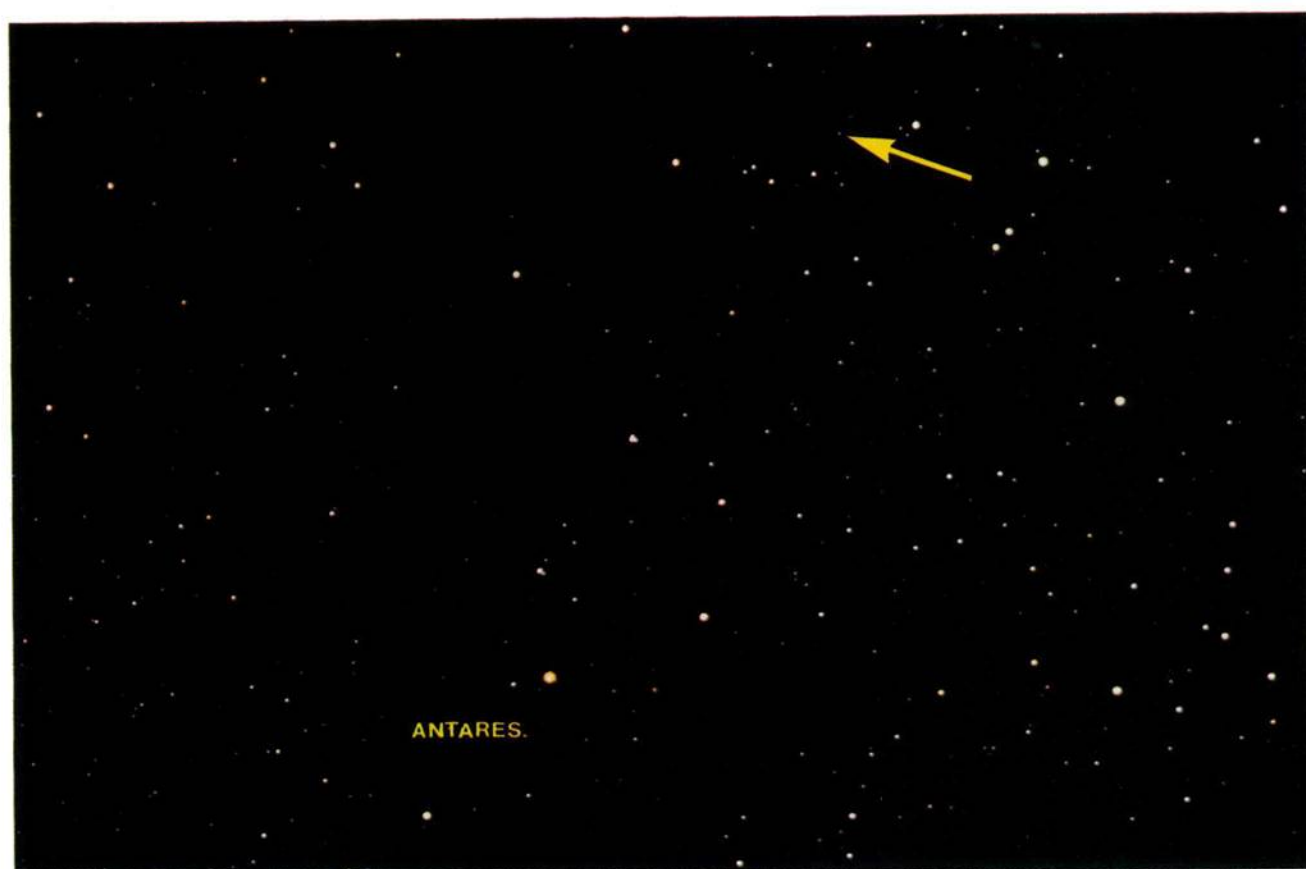
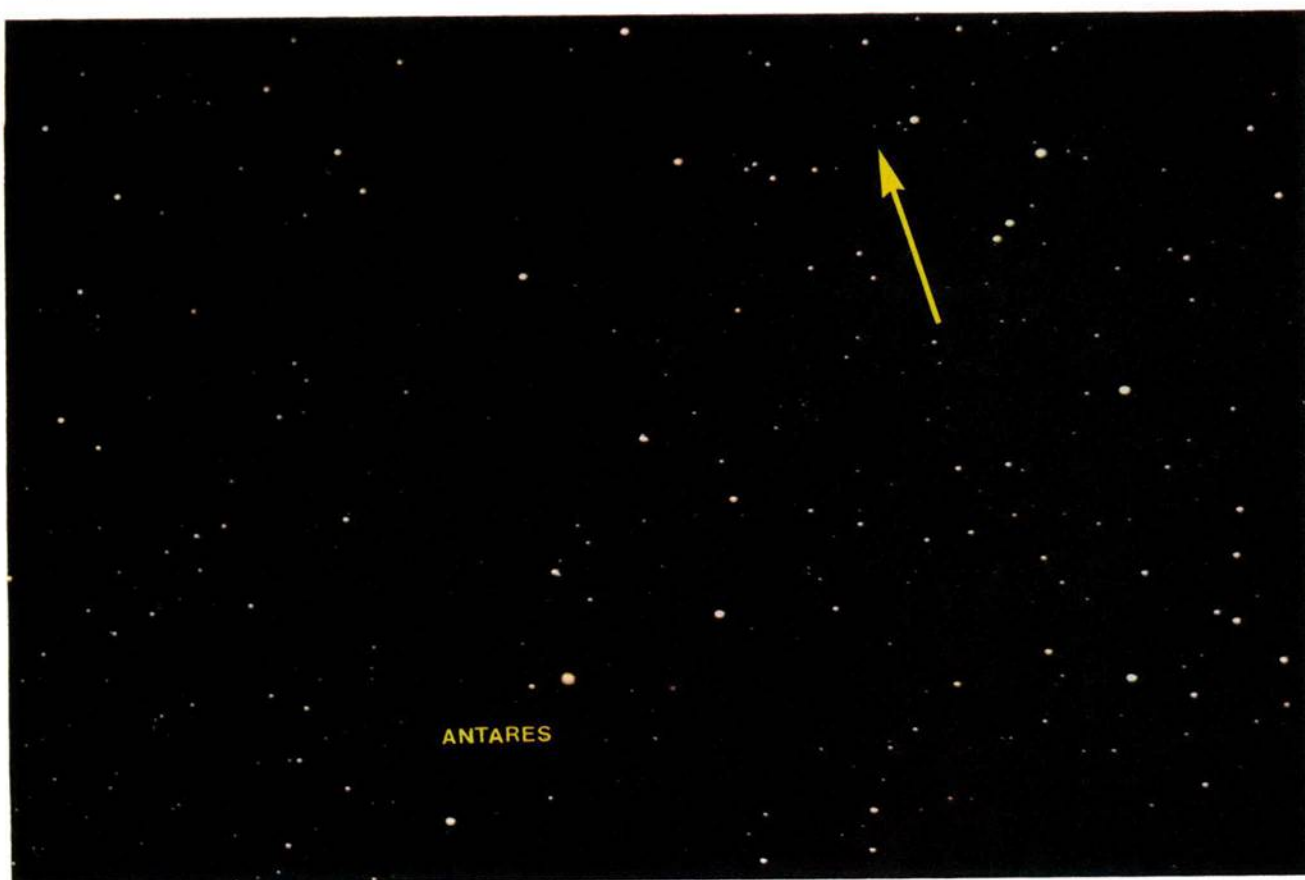
A billion miles beyond Uranus is another giant planet with a deep gaseous atmosphere, similar in many ways to Uranus. It's Neptune. A small telescope will usually only show it as a star. At least a six inch telescope is needed to perceive its disk — bluish-green and similar to Uranus.

And a billion miles farther still is Pluto, a tiny world about the dimensions of Mars. Pluto is by far the most difficult planet to observe. Even the world's largest telescopes don't show any details on its surface. Indeed, very few astronomers have ever seen it.

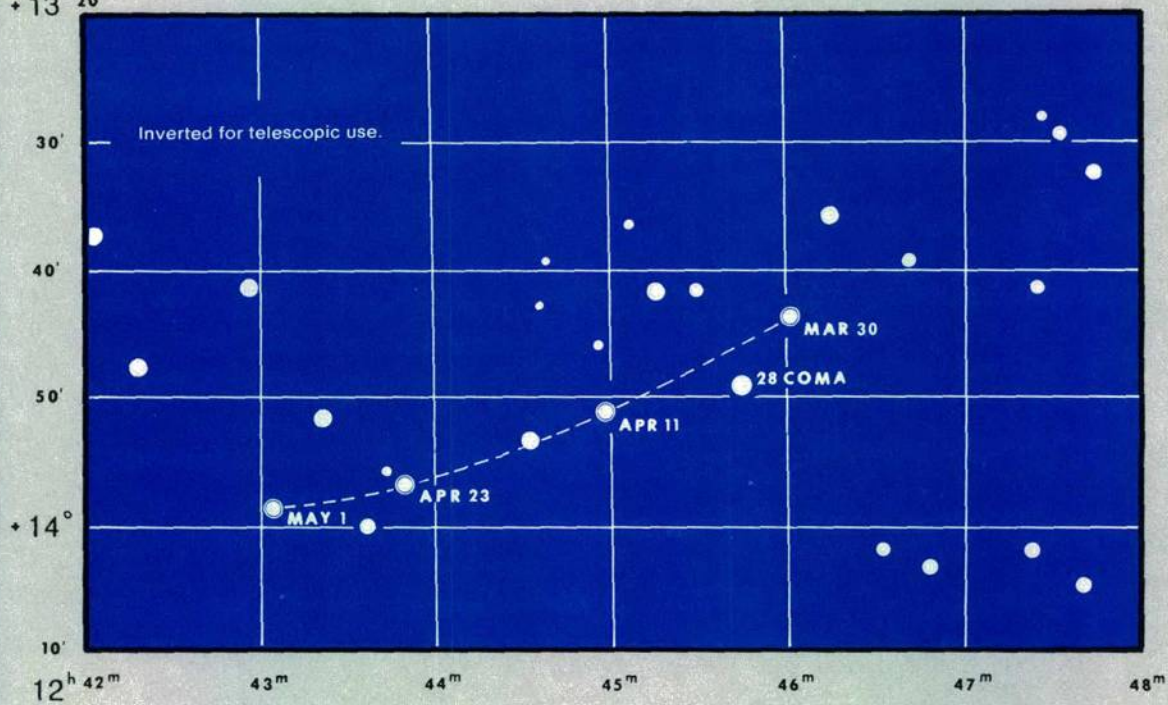
It's easy to talk about how much can (or can't) be seen on Uranus, Neptune and Pluto with various telescopes. One reads these kinds of statements in many astronomy books but it's not enough just to describe the difficulty in observing these planets. The biggest challenge and satisfaction in observing them is in the finding. The charts included on these pages are specifically designed to make it easy to find Uranus, Neptune (and even Pluto if your telescope is large enough). For Uranus, all you need is a pair of binoculars; for Neptune, a two inch telescope will do. But for Pluto, at least an eight inch scope and excellent skies are required to pick up the 14th magnitude planet. Both Uranus and Pluto are now in ideal positions for observation and Neptune will be in another month or so.

No special equipment is required. Setting circles are not necessary. All you need to know is

These two photos of the northern portion of Scorpius contain faint images of Neptune (arrows). During July 1973, the 8th magnitude planet moved through only a small portion of the constellation. By guiding a 35mm SLR camera attached to his telescope, Jandorf obtained these 5 minute exposures on High Speed Ektachrome. The lower photo was taken July 1; the upper on the 30th. Compare the photos to the Neptune charts in this article.

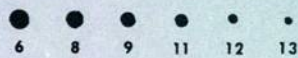


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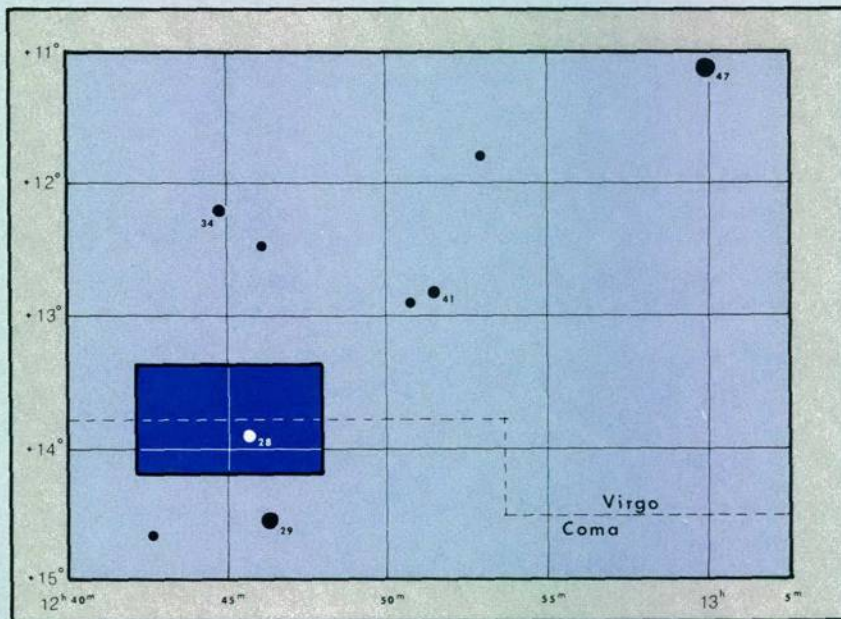
Map by Raymond G. Couthie

Magnitudes



Pluto
1974

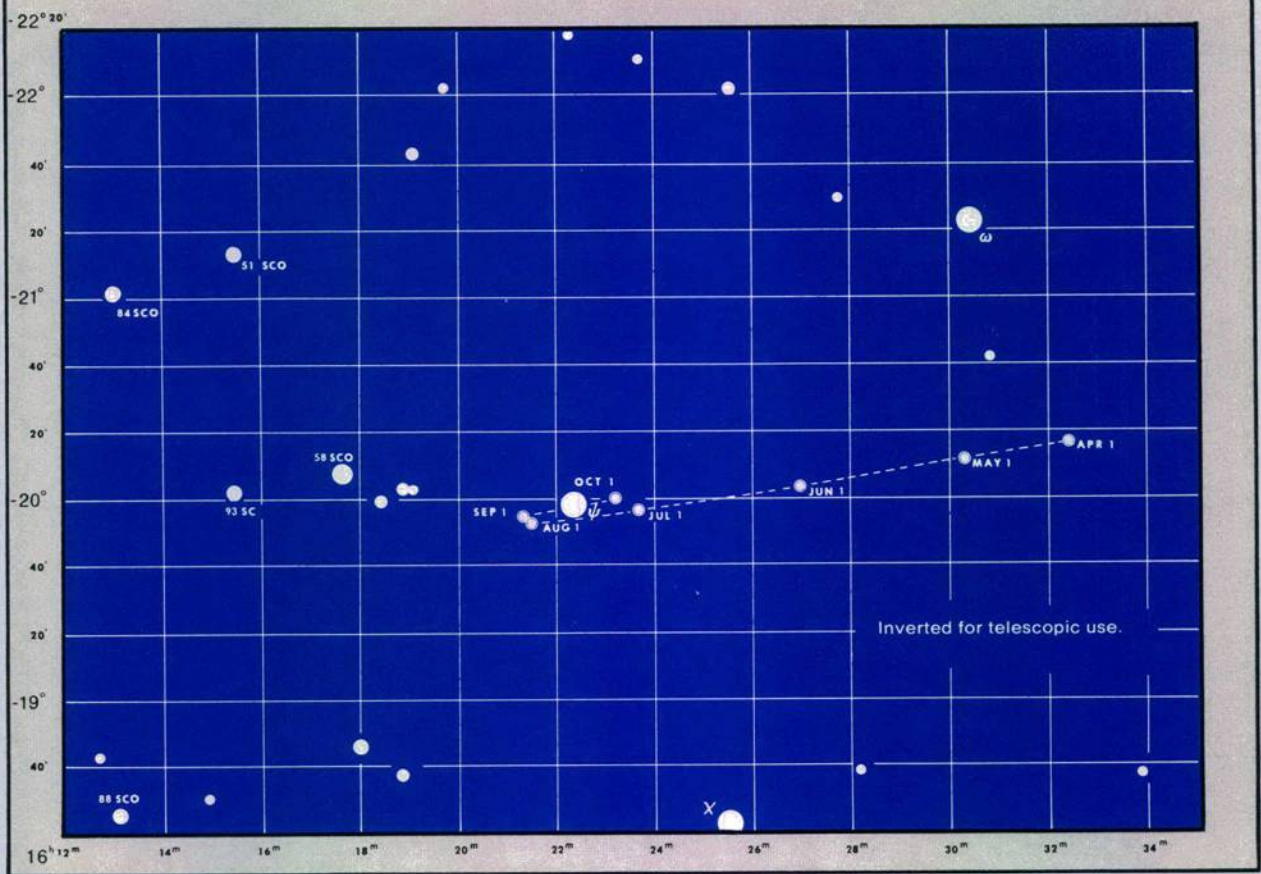
Large chart is a detailed blowup
of boxed area in smaller finder
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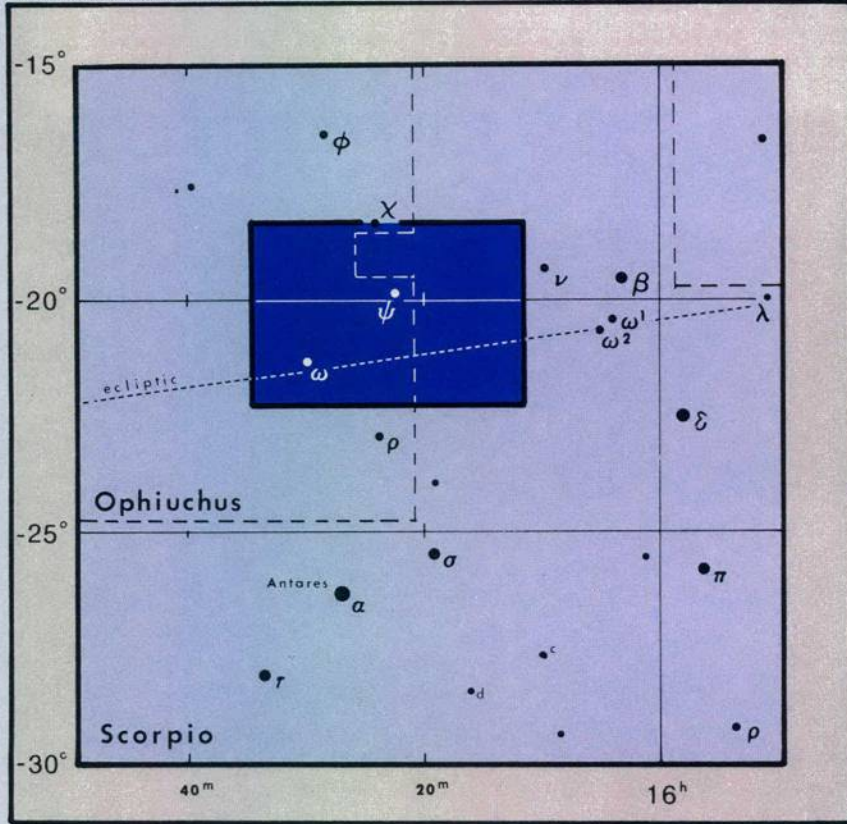
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Magnitudes

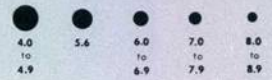




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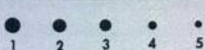
Magnitudes



Neptune
1974

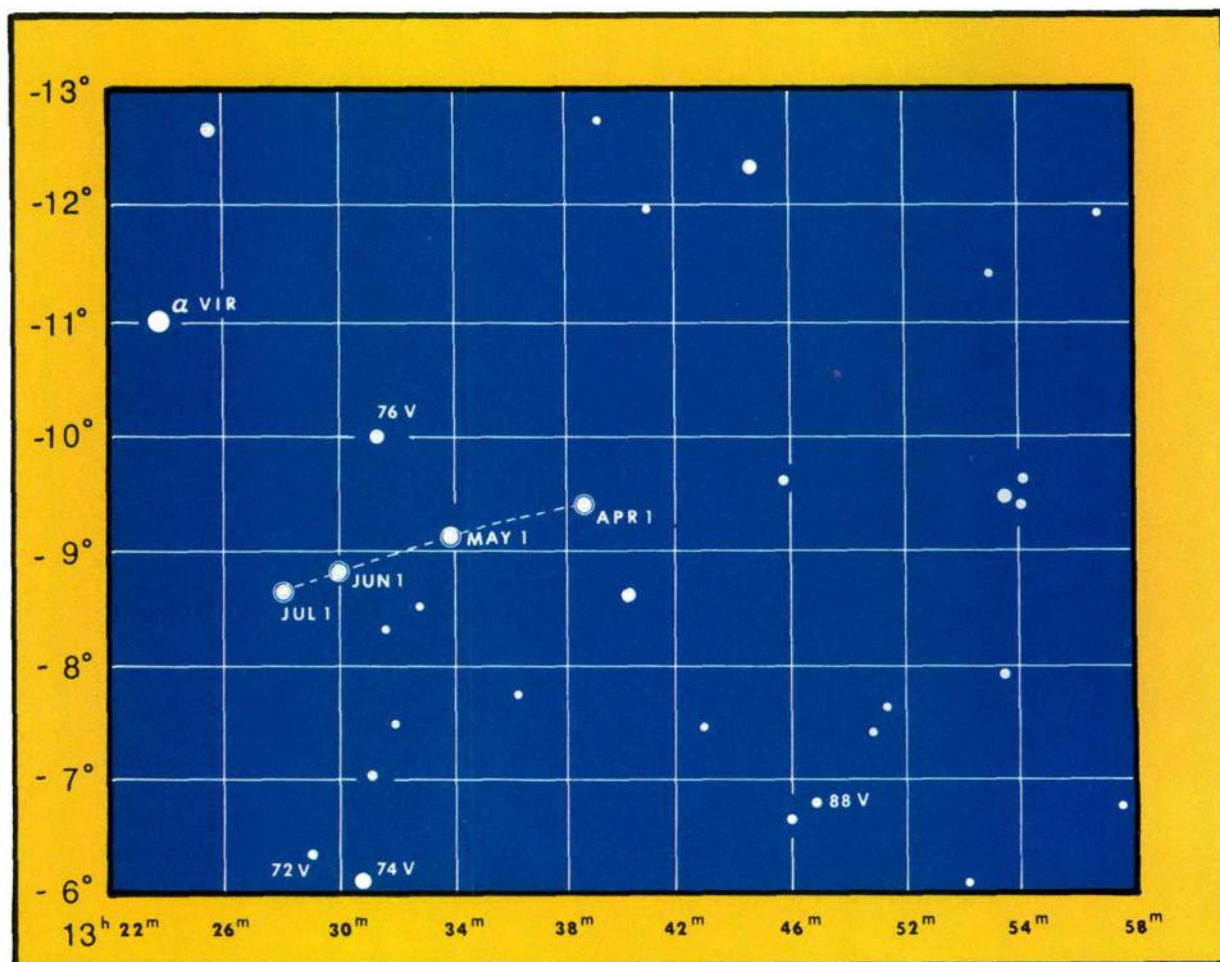
Large chart is a detailed blowup of boxed area in smaller finder chart.

Magnitudes



Map by Raymond G. Coutchie

Uranus 1974



how to find Virgo (for Uranus and Pluto) and Scorpius (for Neptune). The finder charts for Neptune and Pluto have bright naked eye stars in them and Spica is within the Uranus chart. The bright stars in the finder chart can be related to Star Dome (page 32) for general orientation. The stars on the Neptune finder chart are not on this month's Star Dome but are shown in the photographs on page 49.

Center your finder scope on the naked eye star marked on the chart and move, by going from star to star, to the boxed area. Or if you are hunting Uranus you can zero in on the planet directly.

Photographing Uranus is easy. Simply aim your camera at the general region and open the shutter for 10 seconds — the same procedure used to photograph constellations. To capture

Neptune on film, however, requires guiding since it is two magnitudes fainter (Uranus is 5.7 and Neptune 7.7). The five minute guided exposures opposite the first page of this article give some idea of the results possible.

Pluto photography is beyond the means of virtually all amateur astrophotographers. Finding Pluto visually is enough of a challenge. Generally a 12 inch telescope is needed for Pluto hunting. It has been seen by sharp eyed observers using six inch scopes under excellent sky conditions, but such reports are rare.

Seldom can an astronomy enthusiast boast that he has seen all eight other planets in the solar system. But who needs to boast anyway? We scan the skies for our own quiet satisfaction and in doing so become acquainted with the incredible universe of which we are a part. ☛

ASTRO-NEWS

Latest News From the World of Astronomy

Mariner 10 Photographs Venus

The planet Venus, Earth's nearest neighbor in space, has long been one of the most mysterious worlds in the solar system. Shrouded in impenetrable clouds, the planet has rebuffed many attempts at exploration.

Mariner 10, an unmanned spacecraft launched in Nov. 1973, passed within 3,585 miles of the planet's surface on Feb. 5, 1974, taking hundreds of photographs of the tops of clouds that have been the nemesis of astronomers for decades. From Earth those clouds give the planet an appearance not unlike a featureless ping pong ball. But the new spacecraft photos show detail never before seen on Venus (see next page).

No previous spacecraft passing near Venus has been equipped with cameras, so no one really had any idea what to expect.

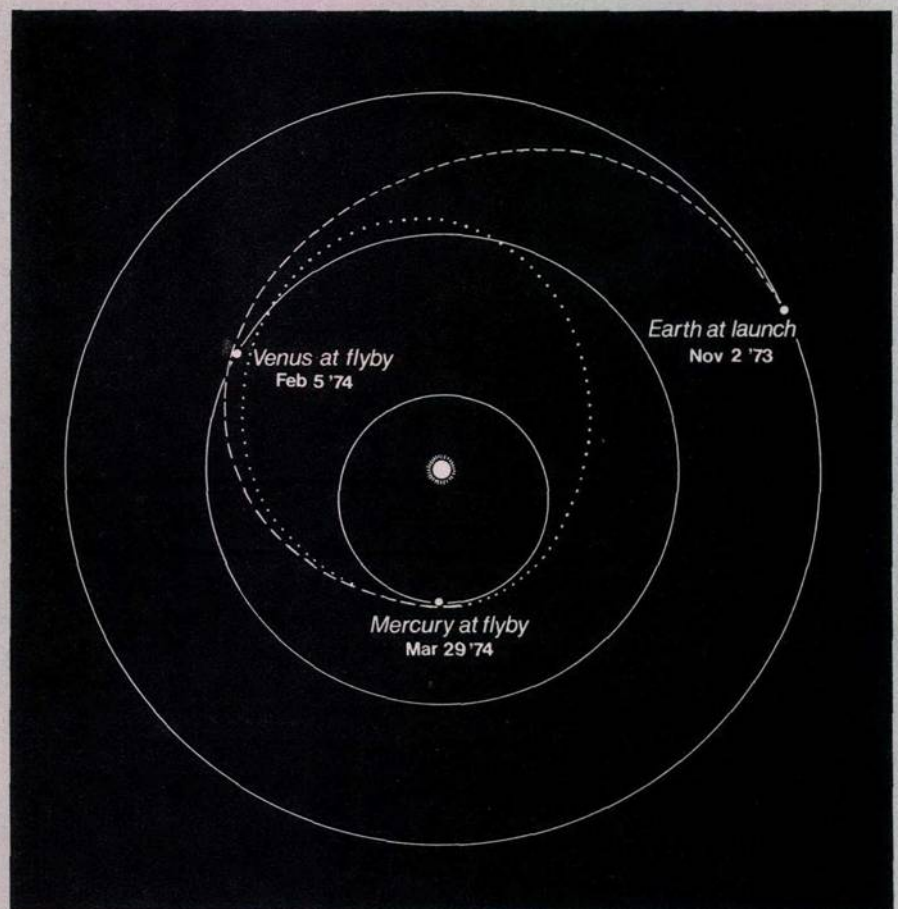
From Earth, Venus has always appeared virtually featureless even when viewed through extremely powerful telescopes. However, photographs taken in ultraviolet light from Earth have shown dark patches in the clouds of Venus suggesting that detail within the clouds would be there if we could only get a clear look at it. Consequently the Mariner 10 cameras were equipped to photograph the planet in ultraviolet light.

As the craft went swinging by Venus on Feb. 5, it successfully took hundreds of pictures — and hundreds more on each of the following five days. The photos have confirmed that the dark areas, seen as dark patches from Earth, are indeed part of a planet-wide cloud and wind circulation system. The increase in resolution, from 600 mile wide swatches glimpsed from Earth to Mariner 10's detection of zones as small as six miles across, is a remarkable increase in our knowledge of the cloud structure of our nearest plane-

tary neighbor. The circulation pattern seems to be relatively simple at least upon first inspection. The planet is heated by the sun at the equator. The heated atmosphere and clouds rise, flow toward the poles, and from there descend to complete the cycle.

Dr. Verner E. Suomi, a member of the Mariner 10 imaging team, explained that the clouds appear like earthly cirrus clouds indicating that there is convection action within them. That is, parts of the atmosphere are rising

continued on page 54



Mariner 10, the first spacecraft to explore two planets, was flung by Venus' gravity on to a trajectory over the night side of Mercury. Once beyond Mercury, mission planners hope to adjust the craft's orbit to make it return to the inner planet 176 days later (dotted orbit). This second flyby, if successful, will yield photographs of the smallest planet's polar region.

and other parts falling with condensation forming. So the implication is that at least these upper atmosphere clouds are similar to high clouds in Earth's atmosphere.

Dr. Bruce Murray, a principal Mariner 10 scientist, commented that none of the project scientists had predicted the complexity of the Venus cloud structure that had in fact been observed by the ultraviolet cameras. He said the photos show three and possibly four distinct layers of clouds.

The cameras also took photographs in visible light, duplicating the view that a human would have if he were seated on the spacecraft as it hurtled by Venus. But even at such close range, to the human eye the planet would still appear almost featureless; the photographs in visible light revealed very little cloud structure. Murray remarked that Venus looked like Mars did when Mariner 9 arrived there during the planet-wide dust storm in 1971. Even on viewing the terminator

(the area between the illuminated and unilluminated portions of the planet), no cloud structure was discernible — at least in the initial viewing of the photographs.

Other experiments on Mariner 10 confirmed that the planet's atmosphere is extremely dense and contains no detectable oxygen. Its magnetic field is less than 1/20 of one percent as intense as Earth's. This is in keeping with the theory that planets with rapid rotation have intense magnetic fields



NASA Photograph

Mariner 10 television cameras took this sequence of pictures on Feb. 6 when it was 525,000 miles from the planet. The cloud circulation seen here is visible only in ultraviolet light. The pattern of dots is for calibration purposes and will be removed by computer processing.

(Jupiter and Earth for example) and planets with slow rotations, like Venus, have virtually nonexistent magnetic fields.

There seems to be virtually no magnetosphere, a protective zone that exists around Earth suspended by its magnetic field and shielding our world against the intensity of high energy particles from the sun and deep space.

Another Mariner 10 finding is that Venus is much more nearly round than Earth by a factor of 100. Earth is 27 miles wider at the equator than it is at the poles but Venus deviates from a sphere by less than one mile on the average.

Venus is about the same size as Earth but has an atmosphere of mainly carbon dioxide, 100 times as dense as ours. If Earth were as close to the sun as Venus, it would probably be a similar world. At Venus' distance (about 2/3 Earth's 93 million miles) the sun's heat is great enough to evaporate oceans, releasing much of the carbon and oxygen trapped in the water and land of our planet. Some scientists have calculated that if Earth was only four million miles closer to the sun it would be like Venus.

The nature of the surface of the planet recently came into focus when two Russian spacecraft, Venera 7 and 8, landed on Venus in 1970 and 1971. Each craft operated there for several minutes and measured temperatures of 880 degrees above zero. They recorded the surface temperature on the planet's night side to be almost the same as the daytime side's — the density of the atmosphere easily holding in much of the heat absorbed from the sun. According to Mariner 10 data the cloudtop temperatures are much lower, averaging -35 degrees.

Despite all this new information the paradox remains. Why is Venus so totally different from Earth despite the fact that it is the only other planet in the solar system that is approximately the same size and mass as our world? The concept that Venus possibly was initially like Earth but had its water evaporated to form the dense atmosphere is perhaps too simplistic. For example, not a trace of deuterium (a heavier form of hydrogen) was detected by Mariner 10. This has several implications.

First, if the dense atmosphere of Venus was caused by the initial water of the planet being evaporated and dissociated into hydrogen and oxygen, deuterium would be a common commodity in the atmosphere. It now looks like Venus never had any water. When the planet was initially forming, the fact that it didn't have much of a magnetic field may have allowed the solar wind to blast, unimpeded, at the basic elements in the planet's initial

New Mars Film

An excellent documentary film on the results of the Mariner 9 mission to Mars has been released by NASA. Titled "Mars — The Search Begins", the color film reviews new knowledge gained about the planet from more than 7,000 pictures returned to Earth from the spacecraft. Particular attention is paid to the possibility of finding life forms on future missions to the red planet. The film was previewed by delegates attending the International Colloquium on Mars in Nov. 1973, and is now available for public showing.

Three-dimensional views of models of Mars' surface features as they are now known introduce realism into the film, as if the viewer was walking on the Martian surface. Photography of the surface models simulates a variety of sun angles, representing views from various heights or overhead spacecraft — with shadows emphasizing the rugged character of massive canyons and other elements in the Martian landscape.

A considerable portion of the film

atmosphere, and the original hydrogen would have been blasted into space.

Second, about 10 times more oxygen than expected was detected in the upper layers of the Venus atmosphere. This suggests that circulation in this zone is rampant but lower layers are rigidly structured with relatively little mixing between layers. Apparently the upper layers (the part visible in the photograph opposite) are whipped by 200 m.p.h. or greater winds. But the net result seems to be almost no circulation or wind down at lower levels. In addition the Soviet Venus landers also detected virtually no wind at the surface.

So Venus is a furnace down at ground level with stifling dense carbon dioxide atmosphere far above the boiling point of water over the entire surface of the planet. Farther up tremendous jet streams whip the highest layers of the atmosphere into a beautiful tapestry of cloud patterns. It all implies that somehow Venus is the odd man out in the solar system or, alternatively, one can say that each planet must be examined as an individual world essentially unrelated to its brothers in the sun's family.

Perhaps the real difference between Earth and Venus stems from the difference in rotation. Venus rotates in 243 of Earth's days — a number that has led to considerable confusion in astronomy books. The 243 days refers to the planet's rotation with reference to the stars rather than with

is given to graphic portrayals of types of organisms which could exist on Mars, with models picturing botanists' and zoologists' conceptions of how they might live and propagate. Commentaries are provided by Dr. Carl Sagan, astronomer and exobiologist at Cornell university's Laboratory for Planetary Studies; Harold Masursky, United States Geological Survey geologist, Flagstaff, Ariz., and Dr. Gerald Soffen, biologist at NASA's Langley Research Center. These scientists observe that the Mariner 9 pictures can be interpreted as providing fresh evidence that some forms of life could exist on Mars. The photos have also provided researchers with indications of where to look for such phenomena.

The editors of *Astronomy* highly recommend this well produced 28 minute, 16mm film. Educational and civic organizations or individuals wishing to purchase or acquire the film on loan should address their inquiries to Mr. Frank K. Grimm, Code FAM, NASA Headquarters, Washington, DC 20546; telephone (202) 755-3500.

reference to the sun. The actual length of the Venus day is 117 Earth days; that is, 117 days from one sunrise to the next. The difference comes about because not only is Venus's rotation extremely slow but it's also backward. The sun rises in the west and sets in the east resulting in an extremely complicated rotation/revolution relationship.

With such a slow rotation the initial heating of the sides of Venus facing the sun must have given it a very different early history than that of Earth. The fundamental question is why Venus has such a leisurely rotation rate and also why it rotates backward while all the other planets, at least out to Saturn, rotate in the same direction that Earth does. Undoubtedly this problem is going to be unresolved for some time and yet it is the key to understanding the mysteries of our very unearthly neighboring world.

Mariner 10 is now hurtling toward Mercury, the smallest planet in the solar system. On its swing by Venus, the spacecraft used that planet's gravity for a slingshot-like effect to propel it directly toward the small inner planet. (At press time, encounter with Mercury was due on March 29.)

Recent observations of Mercury by a team of radio-radar astronomers, have produced a picture of Mercury somewhat similar to the moon. There seem to be hills and valleys on the planet as well as large basinlike craters (see companion article).

Radar Distinguishes Hills, Valleys on Mercury

The middle of the planet Mercury appears to be covered with hills and valleys, plus some surface markings that may be craters 30 miles across. These are the latest findings of a team of radar astronomers at Caltech's Jet Propulsion Laboratory (JPL). The hills and dales vary by about 3,000 feet in elevation, and the craterlike features appear to be about 2,000 feet deep.

The discovery was made by Drs. Richard M. Goldstein and Shalhav Zohar of JPL. By directing high powered beams at Mercury, some 55 million miles away, they took what Goldstein terms "a series of snapshots" of the planet closest to the sun. The snapshots — 14 radar probes during the last half of 1972 — produced the following panorama of equatorial Mercury.

Five or more areas probed reflected circular features that are likely to be craters averaging 30 miles in diameter. Two experiments indicated several craters might be 300 miles across but, added the authors, "we treat this possibility with some reserve."

While most of the hills seem to be gradual or gently undulating, one experiment indicated a promontory rising to about 4,200 feet from a 75 mile wide base. The radar team's discoveries may be verified Mar. 29 when Mariner 10 is scheduled to fly by and take the first close-up photographs of Mercury. The Mariner-Venus-Mercury spacecraft was launched Nov. 3, 1973, on history's first dual-planet flight.

The 14 JPL radar scanings of Mercury occurred between July 15 and Dec. 8, 1972, with the astronomers using

the Goldstone station's 210 foot transmitter on California's Mojave desert, to send the 2.388 GHz signal and, alternately, to receive the returned signal. Transmitting power is 400 kilowatts on a 12.5 centimeter wavelength. The so-called echo returns in about 10 minutes with a power of a very tiny fraction of a watt. These echoes, charted and averaged over several hours in each test, show the differences in the surface of the planet being probed. Months of computer work are required to analyze the data and formulate a map of the radar findings.

In previous radar probes, the JPL team had scanned the whole planet at low resolution. In the latest tests, they zeroed in on the equator at high resolution, concentrating on areas between 12 degrees north and 4 degrees south all around the planet's middle. Each snapshot, Goldstein says, covered

an area 400 miles across. Mercury, just over 1/3 the diameter of Earth, measures about 9,000 miles around at the equator.

In 1969 tests, the JPL team established that Mercury has several large, continent-size rough spots, not particularly near the equator. To the radar-men, Mercury appears to be much rougher than Venus, but its distance makes speculation risky. Bouncing radar beams off features on Mercury, Goldstein says, is "like trying to hit a dime at 10,000 miles."

It is a measure of radar astronomy's increasing sophistication that Goldstein and Zohar were able to conclude that while some areas on Mercury appear bland, "other regions on the planet's surface seem to be replete with intriguing shapes and features." How intriguing remains for Mariner 10 photographs to determine. 

Jet Aircraft Pollution Levels Studied

Jet aircraft pollution in the world's airlines will be measured in a new National Aeronautics and Space Administration study to aid scientists in determining effects, if any, of jet exhaust products on the natural environment, weather and human health.

Under the \$1.1 million contract, United Air Lines will develop, test and fly a system on one of its 747 jumbo jets which can measure dust particles and gases in the airlines. Flights will be made over the contiguous United States and Hawaii. Additionally, United will subcontract with an international air carrier (Pan American) to install another system on one of its 747s to sample atmospheric constituents in other parts of the world. The survey may reveal any changes in the level of ozone which shields people on Earth from solar ultraviolet radiation; how much jet vapor trails contribute to cloud cover; and what proportion of dust particles in the airlines is from aircraft.

The Boeing 747 jet was selected to carry the instruments because of its

wide body and modern air data computing system which records such information as location, altitude, air temperature, and air speed. Air sampling equipment is automatically activated once the plane achieves the proper flight altitude. A small tube protruding from the underside of the plane's nose takes in air for analysis.

Initially, the 747s will carry instruments which can detect four constituents: total suspended particles (dust particles), carbon monoxide, ozone, and water vapor. Later in the program, as many as 10 instruments may be carried. Scientists are especially interested in obtaining data on oxides of nitrogen emitted by jet engines. Oxides of nitrogen interact with ozone and destroy it in the upper atmosphere. If not enough ozone is present, harmful ultraviolet rays are not filtered out. NASA will be working closely with the National Oceanic and Atmospheric Administration (NOAA) to correlate results of the study with weather data and assess the effects of man made pollutants on the atmosphere. 

ASTRO-MART

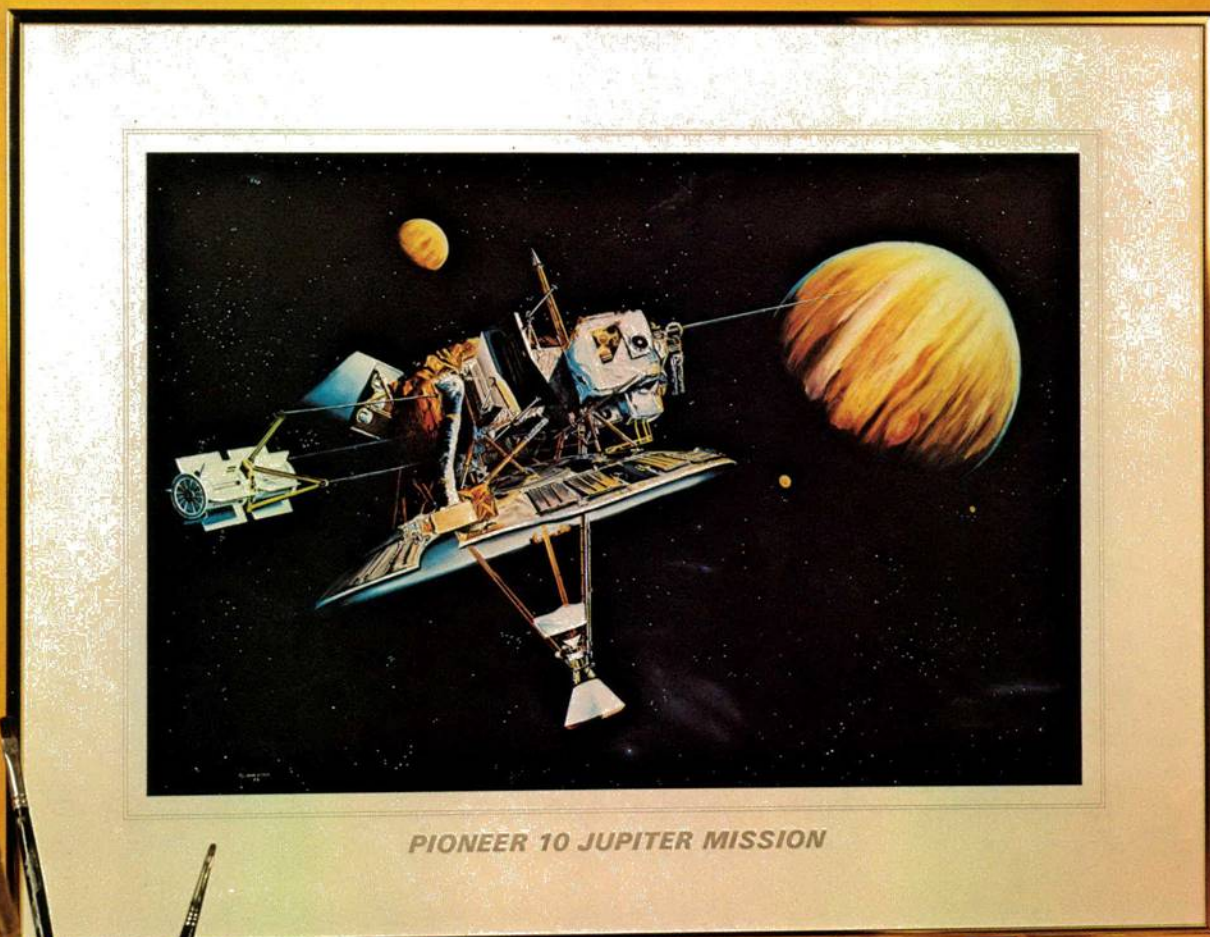
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Pioneer 10 Jupiter Mission

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Pioneer 10's encounter with the planet Jupiter marks a milestone in America's exploration of space. And to commemorate this historic event, John W. Clark, an upcoming space artist, painted an original oil portrait of the encounter with Jupiter. The Pioneer 10 painting was first used as a two page spread to lead off ASTRONOMY's feature "Encounter with Jupiter" in the February issue. And it not only accurately depicts in color all the detail in the Pioneer 10 spacecraft but also the detail and color of the planet Jupiter.

The accuracy of this work of art easily challenges the finest artwork from NASA. Now it is available as a full color lithograph ready for fram-

ing, suitable as decor for any room.

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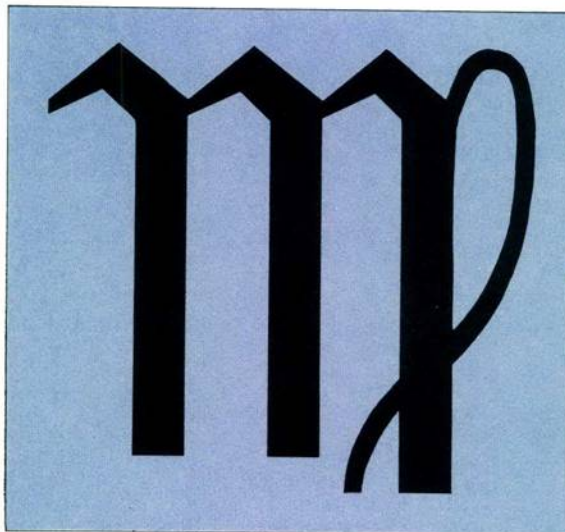
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CONSTELLATION CLOSE-UP

Virgo

by
Thomas C. Bretl



On clear April evenings the sparkling winter constellations are quickly setting, the Summer Triangle is only just rising, and Virgo lies sprawled across the southern sky. The time for observing the beautiful open clusters of winter is past and yet it is too early for the endless star fields of the summer Milky Way. It is the time to search for objects of more subtle beauty and mystery — the distant galaxies.

There is no better place to hunt for galaxies than in Virgo, where, says T.W. Webb (in *Celestial Objects for Common Telescopes*), "a far greater number of these extraordinary bodies are accumulated than in any other equal area of

the heavens."

Sir William Herschel detected more than 300 galaxies in Virgo, and at least 20 can be easily found with an eight inch richest-field telescope. Individually most of them are faint and indistinct, but, "it is the mysterious thronging together of these objects, whatever may be their nature, that opens such a field for curiosity." Armed with a moderate sized telescope, a good map, and a patient hunter's spirit, the sky observer will be kept busy as long as he pleases in this most interesting part of the sky.

The stars of Virgo serve as guideposts to these galaxies, but many are interesting in their

own right as well. Especially noteworthy is Gamma Virginis, a beautiful visual binary with a very eccentric orbit. In 1836, at a separation of only 3/10 of a second of arc, this pair could not be cleanly split with the world's finest telescopes. The separation then increased to 6.2 seconds of arc in 1920, making the double an easy object, but is now decreasing again toward another minimum in 2016. The present separation is 5.2 seconds of arc. Gamma is a particularly striking double star because of the equal magnitudes and identical yellowish colors of its components.

North of Gamma, just west of Epsilon Virginis, is the extraordinarily congested hunting ground for galaxies. Many of them clustered there look much alike — small, faint, and indistinct. The real challenge of the hunt, however, is not just to find one of these elusive nebulae, but rather to find and identify so many in such a small area of the sky.

A good place to start is with M-49, situated between two sixth magnitude stars, about three degrees southwest of Rho Virginis. If looking for the first time, observers may find it easier to look two degrees due west of Rho for 20 Virginis and

then sweep directly south about the same distance to locate the galaxy. M-49 is quite bright, well defined, and very round. It should be an easy object in a four inch telescope.

Much more difficult is NGC-4526, located just one degree east and very slightly south of M-49. It too lies between two stars and appears quite starlike itself, despite its elongated 1 x 7 minutes of arc shape. Even in an eight inch telescope, it would be easy to overlook.

M-61 is also nearby and is much easier to see. It can be found halfway between 16 and 17 Virginis, 3-1/2 degrees southwest of M-49. One of the largest galaxies in this area, it has a bright center and is very easy to spot with an eight inch telescope.

The greatest concentration of galaxies occurs north of M-49, on a direct line between Epsilon Virginis and Beta Leonis. There is so much to be seen here that it is impossible to tell those unfamiliar with this area how to find their way. Each observer must slowly become familiar with the patterns of stars and galaxies in the region until he knows them much like the streets and landmarks of his own home town. A homemade

TABLE OF OBJECTS IN VIRGO

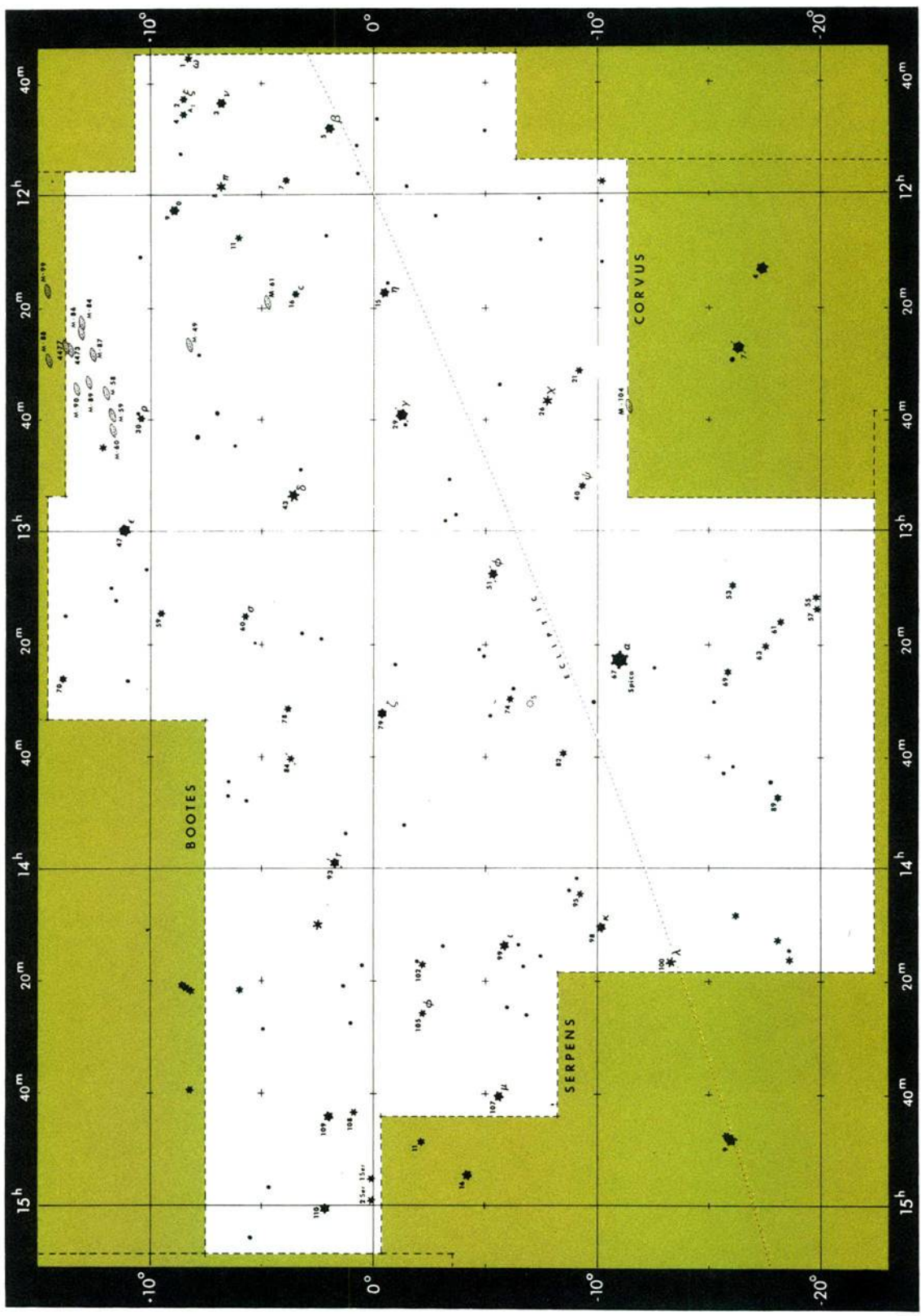
Galaxies

NGC	Messier Object	Magnitude	Size	Type	R.A.	Dec.
4216		10.4	1' x 7'	Sb	12 ^h 14 ^m	+13°18'
4303	M-61	10.1	6' x 6'	SBc	12 ^h 20 ^m	+04°38'
4374	M-84	9.8	3' x 3'	E	12 ^h 24 ^m	+18°03'
4406	M-86	9.7	3' x 4'	E	12 ^h 25 ^m	+13°06'
4472	M-49	8.9	4' x 4'	E	12 ^h 28 ^m	+08°09'
4526		10.9	1' x 6'	Sa	12 ^h 33 ^m	+07°51'
4486	M-87	9.3	3' x 3'	E	12 ^h 29 ^m	+12°33'
4552	M-89	10.3	2' x 2'	E	12 ^h 34 ^m	+12°43'
4569	M-90	10.0	3' x 6'	Sc	12 ^h 35 ^m	+13°19'
4579	M-58	10.3	4' x 3'	SBb	12 ^h 35 ^m	+11°58'
4594	M-104	8.9	2' x 7'	Sa	12 ^h 38 ^m	-11°28'
4621	M-59	9.9	3' x 2'	E	12 ^h 41 ^m	+11°48'
4649	M-60	9.3	3' x 4'	E	12 ^h 42 ^m	+11°43'

Double Stars

Star	Magnitudes	Separation	Color	R.A.	Dec.
γ	3.6 - 3.6	5.2"	Yellow-yellow	12 ^h 40 ^m	-1°16'
17	6.2 - 9.0	19.6"	Yellow-blue?	12 ^h 30 ^m	+5°28'
θ	4.0 - 9.0	7.2"	White-blue?	13 ^h 08 ^m	-5°23'

Epoch 1970



Stellar Magnitudes -1 0 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 & fainter

Diffuse Nebula Double Stars Variable Stars

Galaxies Planetary Nebula Open Star Clusters Globular Clusters



map, drawn at the telescope and later compared with the accompanying map and photograph, may prove very helpful.

Many of the galaxies in this area will look very similar, being of almost identical size and magnitude. Some, however, like M-84, M-86 and M-89 appear more starlike than others and may, in fact, be passed over as stars when viewed under low magnification. The listed magnitudes and angular sizes can also be deceiving, giving an unreliable indication of how easy an object a particular galaxy should be. M-58, for example, has the reputation of being one of the most difficult Messier objects in this area. In general, the larger the object the more its light is spread out and the harder it is to distinguish.

As your hunt takes you westward through this cluster of galaxies, the last in line is NGC-

4216 whose unique appearance makes it a fitting and rewarding end to a night's observing. It is a thin sliver in the sky with a starlike nucleus at the center, a kind of celestial compass needle pointing just east of north.

Should you tire of this hunt and begin to see each new galaxy as just another fuzzy patch, pause a minute and reflect on the true nature of these extraordinary objects. These small "hazy spots" are as immense as our entire Milky Way and they are so numerous that with the largest telescopes, more new galaxies are found than stars. They are so distant that in seeing them we are looking back millions of years into the past, for their light takes that long to span the gulf of space between. Surely, never are our minds given more freedom to wander endlessly through space and time — and wonder at it all. ☛

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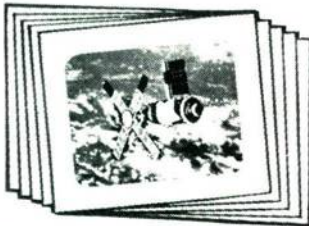
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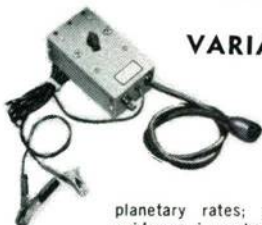
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